Movements of Kemp's Ridley (*Lepidochelys kempii*) and Green (*Chelonia mydas*) Sea Turtles Using Lavaca Bay and Matagorda Bay

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By

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EXECUTIVE SUMMARY

Understanding the habitat needs of sea turtles is recognized as an essential element in successful recovery of their stocks in the Gulf of Mexico (Thompson et al., 1990). Until recently, little research had been conducted on sea turtle populations in Texas, even though Texas inshore waters provide important habitat for Kemp's ridley, *Lepidochelys kempii*, green, *Chelonia mydas*, and loggerhead, *Caretta caretta*, sea turtles.

A preliminary evaluation of the temporal and spatial distribution of Kemp's ridley, green, and loggerhead sea turtles in Lavaca and Matagorda Bays was made 1) to determine if turtles are locally restricted or part of a more extensive group of turtles, 2) to describe their association with specific habitats, (i.e., channels, oyster reefs, seagrass beds, and other areas in the bay) and with geographic areas of the bay, and 3) to address the potential risk of exposure posed to turtles by discharge water from the Formosa Plastics Plant containing potentially toxic substances.

Eight sea turtles (6 Kemp's ridleys and 2 greens) equipped with radio and sonic transmitters were released in Matagorda Bay, Texas, and tracked for 3-18 days a month, from May through November 1996. Three additional turtles (1 Kemp's ridley and 2 greens) were fitted with satellite transmitters and released near Indian Point, in northwest Matagorda Bay, Texas. As of 14 May 1997, one green turtle was still being tracked by satellite telemetry. Sizes and weights of turtles ranged from 31.5-58.4 cm SCL and 4.0-21.7 kg for Kemp's ridleys and from 29.9-37.5 cm SCL and 3.3-7.6 kg for greens.

Typically, radio-tracked sea turtles remained within 3 km of a 20 km stretch of coast along the west side of Matagorda Bay, from Indian Point in the north toward Port O'Connor in the south. However, one Kemp's ridley did cross Matagorda Bay and enter Carancahua Bay and Tres Palacios Bay. Two green turtles, monitored with satellite telemetry beginning in October 1996, increased the

distance of their daily their movements during November and December, after the passage of cold fronts and subsequent cooling of bay waters. Bay water temperatures decreased from monthly summer means near 30° C to less than 17° C in November and December. The turtles apparently sought warmer water when they moved into the Gulf of Mexico on 18 December 1996 and 1 January 1997, and relocated offshore where temperatures were 13-23° C. Both turtles moved to the south. One was in water depths between 10 and 20 fathoms just south of Corpus Christi Bay by 10 January 1997. On 17 January it was an additional 200 km to the south, in the same depth zone, just below the Texas-Mexico border. Its movement was monitored southward for another 70 km when before signals from its transmitter ceased on 30 January 1997. The second green turtle moved approximately 260 km by 2 February 1997; nearly 40 km south of Port Mansfield in water depths of less than 10 fm. It returned to Matagorda Bay, on 2 April 1997. Since its return to inshore waters in March 1997, it has remained in inshore waters and moved through Espiritu Santo Bay toward Corpus Christi, TX. The last recorded position of this turtle was in Aransas Bay on 11 June 1997. It is still being tracked.

We disproved the hypothesis that turtles would use all parts of the bay equally. Data collected during 1996 demonstrated that Kemp's ridleys mostly utilize the shallow areas along the western perimeter of Matagorda and Lavaca Bays. Central and eastern Matagorda Bay and central Lavaca Bay were less frequented by these turtles. Southeastern Matagorda Bay, northern Lavaca Bay and the upper reaches of Carancahua and Tres Palacios Bays were not utilized by turtles in this study. These latter areas are in the immediate proximity of freshwater river inflow, which may discourage use of areas by sea turtles.

The home range (95% utilization distribution) for all Kemp's ridleys combined was bimodal encompassing an area of 436.6 km^2. The northern extent of home range for Kemp's ridley sea turtles roughly corresponded to the Highway 35 Bridge and Causeway in Lavaca Bay, which lies within 2.5 km of the Formosa Plastics discharge site. Home range also included all of Cox and Keller Bays, as well as most of Powderhorn Lake, Carancahua and West Matagorda Bays. An isolated part of the home range of Kemp's ridleys was in Tres Palacious Bay. The core area (64% utilization distribution) for Kemp's ridley sea turtles, encompassing 138.0 km^2, represented approximately one-third of their home range. Green turtles used the southwestern part of Lavaca Bay and the western shores of Matagorda Bay coincident with distribution of seagrass habitats. The home range of green turtles encompassed 19.5 km^2. The area extended approximately 10 km along the western side of Matagorda Bay from 1 km north of Indian Point to 3 km south of Indianola, shoreward of the Matagorda Ship Channel. The core area (53% utilization distribution) encompassed 3.4 km^2, and was approximately 17% of the home range. High utilization of a small portion of the home range is indicative of habitat preference, whether it is due to food availability, water temperature, or other factors such as current structure.

Although the home ranges of green and Kemp's ridley turtles do not overlap with the Formosa Plastics discharge site, the path that the effluents must travel as they are flushed to the Gulf of Mexico traverse the area occupied by these turtles. The home ranges for both turtle species overlap with regions receiving discharge from the Formosa Plastics Plant, and consequently has the potential for impacting these species. For example, changes in salinity or other physical and chemical characteristics of water could discourage sea turtles from entering that area, or indirectly affect prey density or distribution, thereby reducing overall habitat. Although no tracked sea turtles were closer than 10 km to the discharge site, suggesting low frequency of occurrence, this does not preclude their use of that area. For example, degree of habitat use of the upper bay may vary annually. The distribution of sea turtles relative to industrial discharge from the Formosa Plastics Plant in Lavaca Bay would be clearer if data were collected over a period of 3-5 years. In particular, seasonal movements and whether the same or different turtles return year-after-year could be documented with additional tracking data.

INTRODUCTION

All sea turtles in US waters are threatened or endangered, and are protected under the Endangered Species Act of 1973. Understanding the habitat needs of sea turtles is recognized as an essential element in successful recovery of their stocks in the Gulf of Mexico (Thompson et al., 1990). Until recently, little research had been conducted on sea turtle populations in Texas, even though Texas inshore waters provide important habitat for Kemp's ridley, *Lepidochelys kempii*, green, *Chelonia mydas*, and loggerhead, *Caretta caretta*, sea turtles.

Historically, green turtles were common throughout the Texas Laguna Madre, and as far north as Matagorda Bay. A commercial fishery for green turtles in these regions accounted for 22,000 kg of turtles in 1890. Loggerheads and Kemp's ridleys were taken less frequently by the fishery. Three turtle packeries were located in West Matagorda Bay alone, between Indianola and Indian Point. By 1900 turtle populations had been overexploited and the fishery collapsed (Doughty, 1984). The commercial netting of turtles essentially became nonexistent after 1902. Now, new threats to the survival of all turtle species have surfaced. Commercial shrimping has by far the most impact on sea turtle populations (Magnuson et al., 1990; Alverson et. al., 1994). In Texas, shrimping effort has been directly correlated with the number of sea turtle strandings (Caillouet et al., 1991, 1996). Other human activities affecting sea turtle survival include hopper dredging, recreational fishing, gill netting, longlining, entanglement by man-made debris, purse seining, boating, chemical pollution, and habitat loss (Magnuson et. al., 1990). All these issues are important to some degree and each should be addressed individually.

The objective of this study was to conduct a preliminary evaluation of the temporal and spatial distribution of Kemp's ridley, green and loggerhead sea turtles in Lavaca and Matagorda Bays 1) to determine if turtles are locally restricted or part of a more extensive group of turtles, and 2) to describe their association with specific habitats, (i.e., channels, oyster reefs, seagrass beds, and other areas in the bay) and with geographic areas of the bay. Additionally, we measured the extent of movements to consider whether sea turtles leave the bay in the fall and overwinter elsewhere. We hypothesized that turtles would use all parts of the bay equally, including the immediate discharge site of the Formosa Plastics Plant. The opposing null hypothesis was that some areas are used more than others.

METHODS

Study Area

The study was conducted in Lavaca Bay and West Matagorda Bay, Texas, the region of Matagorda Bay to the west of the Colorado River (Fig. 1). Unless otherwise stated, the use of Matagorda Bay in this report will refer to West Matagorda Bay. Fishing communities of Port O'Connor and Indianola border the west side of Matagorda Bay, an area of mostly mud and sand bottom less than 4 m in depth. Seagrass (submerged aquatic vegetation) beds occur along its southwestern, southern, and northeastern shores. Oyster reefs are not common in Matagorda Bay. For the most part, Lavaca Bay is similar to Matagorda Bay in habitat types and it ranges in depth from 0.3-2.0 meters. Oyster reefs are present along its margin but sea grass beds are notably absent. The Matagorda Ship Channel cuts through the western extremity of the Matagorda Peninsula. Generally it lies within 3 km of the western shore of Matagorda Bay, and joins the Lavaca Ship Channel servicing Port Lavaca and Port Comfort, major sea ports in Lavaca Bay. Numerous spoil sites, some forming small islands, are present along these ship channels. The brackish water discharge site of the Formosa Plastics Plant is located on the east side of Lavaca Bay, just north of the Highway 35 Causeway.

Capture and Holding of Sea Turtles

Sea turtles were captured by personnel from Texas A&M University's Institute of Marine Life Science, using entanglement nets set at locations along the western edge of Matagorda Bay. The turtles were held up to 96 hours in rectangular (0.8 X 0.5 m) or circular (3.0-m diameter) fiberglass tanks for collection of blood and fecal samples and for photographic documentation. Water depth in tanks was approximately 0.5 m. Straight and curved carapace lengths (SCL, CCL) and widths (SCW, CCW) were measured to the nearest 0.1 cm. Each turtle was tagged on the right and left front flippers using inconel tags and with pit tags placed in the right front flipper.

Radio-Sonic Telemetry

Radio transmitters (164.0-165.0 MHz) were attached to the anterio-medial carapace scutes of turtles using fiberglass resin and cloth. Sonic transmitters (30-81 KHz) were wired through the most posterior marginal carapace scute of each turtle (Renaud, 1995; Renaud et. al., 1995; Gitschlag, 1996). Turtles, were released within 1 km of their capture site, were allowed 24 hours to accustom themselves to carrying the radio transmitter in the natural environment before data were used for analyses, and were tracked by boat (25' Sea Ox). Radio transmitters were monitored, from a distance of up to 11 km, using a Telonics TR2/TS1 radio receiver/scanner connected to a directional 5-element Yagi antenna. Sonic transmitters were monitored using a Sonotronics directional hydrophone with a receiving range from 2-5 km.

The radio receiver and Yagi antenna were used to get initial bearings to turtles when they were on the sea surface. The sonic receiver was used to pinpoint (visual sighting) a turtle's locations. We monitored by radio from land when weather prohibited tracking on water. Turtle locations were ranked according to their accuracy. The most accurate location was based on the visual sighting of the turtle. The second-most accurate location was based on sonic telemetry without visual confirmation. Locations determined by radio-triangulation were the least accurate.

Location data was used to determine position, water depth and distance from shore. With a few exceptions, data were collected between 0800 and 1700 h. Obtaining locations for each turtle was attempted every 1-2 days. Visual sightings of radio-tracked sea turtles or their positions as determined by sonic telemetry were recorded using a Global Positioning System.

Satellite Telemetry

Satellite transmitters (Platform Transmitter Terminal or PTT) were fiberglassed to the anterio-medial scutes of sea turtles (Renaud and Carpenter, 1994; Renaud et. al., 1996; Plotkin, 1995). Turtles were released within 1 km of their capture sites and monitored until signals were no longer received from the PTTs. Location data were transmitted (401.65 MHz, 50 sec pulse interval) at alternating 6-hr periods for the life of the batteries. Battery power of the PTT was conserved by not transmitting when the tag was under water. Data collected from Service Argos Inc. (SAI)[1], by phone modem, included 1) PTT identification number, 2) latitude and longitude of PTT, 3) location reliability index, 4) date and time of PTT transmission, 5) date and time of the previous PTT location, and 6) the number of transmissions used to calculate a PTT position fix. Turtles were allowed 24 hours to accustom themselves to carrying a PTT in the natural environment before data were used for analyses. Location data were used to determine position, water depth and distance from shore. Satellite data were analyzed by season (Spring = Mar-May, Summer = Jun-Aug, Fall = Sep-Nov, Winter = Dec-Feb) when possible. Maps of turtle migrations were produced using MAPP for IBM-compatible computers[2] and Atlas Pro for MacIntosh computers.

Study Period Ranges

[1]Service Argos Inc. 1801 McCormick Drive, Suite 10, Landover, MD 20785, 256 p.

[2]MAPP program was developed by Dennis Koi, a computer technician at the National Marine Fisheries Service, 4700 Avenue U, Galveston, TX 77551.

Study period ranges and core areas were determined for Kemp's ridley and green sea turtles[3]. Range and core area were estimated for individual turtles if location data were available on at least 20 different days. Range was defined as the area encompassing the 95% utilization distribution. Core area was defined as a central area which receives consistent or intense use (Kaufmann 1962). Core area size was considered to be the maximum area in which the observed utilization distribution exceeded a uniform distribution. When no core area could be discerned by this method, a potential core area corresponding to the 50% utilization distribution was outlined. To increase independence between locations, only the most accurate location per day for each turtle was retained for analysis. We ran trials with the data sets comparing the harmonic mean method (Dixon and Chapman 1980) to the minimum convex polygon (Mohr 1947) and various ellipse (Jennrich and Turner 1969, Samuel and Garton 1985) methods. The harmonic mean method appeared to give the best estimate of the area of distribution, even with the small data sets. Therefore, it was used in final range analysis.

Submergence and Surface Durations

Submergence and surface durations and the total amount of time, in percent, spent under water were characterized using descriptive statistics (range, min-max, mean, standard deviation, standard error) for all turtles combined, each species and individual sea turtles. This information provides a means of testing sea turtle behavior in Lavaca Bay against that of turtles from other bays and other situations. Presumably, similar submergence and surface durations means that the sea turtles are behaving normally.

Environmental Data

Air and water temperature, surface water salinity, sea state, cloud cover, wind speed and

[3] Ackerman, B. B., F. A. Leban, M. D. Samuel and E. O. Garton. Department of Wildlife, University of Idaho, Moscow, ID 83843.

direction were measured at the time positions were obtained for the turtles. Descriptive statistics listed in the previous section were used to describe variability in these environmental parameters during this study. Sea turtle behavior will be discussed with respect to changes in these environmental parameters, when feasible, and the behaviors compared to turtle behavior in related research.

RESULTS

Capture and Tagging of Sea Turtles

Eight sea turtles (6 Kemp's ridleys and 2 greens) equipped with radio and sonic transmitters were released in Matagorda Bay, Texas, and tracked for 3-18 days a month, from May through November 1996. Three additional turtles (1 Kemp's ridley and 2 greens) were fitted with satellite transmitters and released near Indian Point, in northwest Matagorda Bay, Texas. Sizes and weights of turtles ranged from 31.5-58.4 cm SCL and 4.0-21.7 kg for Kemp's ridleys and from 29.9-37.5 cm SCL and 3.3-7.6 kg for greens (Table 1).

Kemp's Ridley Sea Turtles

Short Range Movements.

Kemp's ridley turtles were fitted with radio and sonic tags to monitor their short-term movements. Typically, they remained within 3 km of shore along a 20 km stretch of coast on the west side of Matagorda Bay, from Indian Point in the north toward Port O'Connor in the south.

Kemp's ridley 4191 (subadult male; Fig. 2) was released on 28 May 1996 near Indian Point, TX. Over the next 31 days, it moved approximately 40 km to the northeast side of Matagorda Bay, entering Carancahua Bay for 4 days during the first week of June, and ending in Tres Palacios Bay. The last transmission received was on 27 June, from Tres Palacios Bay.

Kemp's ridley 5601 (subadult male; Fig. 3) was also released on 28 May 1996 near Indian Point, TX, and tracked for 66 days. On 1 June 1996, this turtle was within 5 m of the outflow of a pipeline suction dredge working in the Matagorda Ship Channel. Over the next 26 days the turtle remained within dredge plume, 5-100 m from the dredge and its pipeline. During this period the dredge moved approximately 5 km along the Channel toward the Gulf of Mexico. Kemp's ridley 5601 exhibited the furthest movement to the south, approximately 17 km. It was last located on 1 August 1996 within 4 km of Port O'Connor, TX.

Kemp's ridley 5001 (subadult female; Fig. 4) was released on 22 June 1996 near Indian Point, TX, and tracked for only 7 days. During the first two days of its release, the turtle moved 10 km toward the center of Matagorda Bay. By the third day of tracking, it had returned to within 1 km of the beach. This turtle was last located on 28 June 1996 about 5 km northeast of the entrance to Powderhorn Lake.

Kemp's ridley 4811 (subadult male; Fig. 5) was released on 24 July 1996 off near Indian Point, TX, and tracked for 9 days. It moved 6.5 km to the southeast in two days and entered Powderhorn Lake, where it remained for 4 days before reentering Matagorda Bay. It was last located on 2 August 1996 near Indian Point.

Kemp's ridley 5801 (subadult female; Fig. 6) released on 30 July, 1996 off of Indianola Beach Park, TX, was monitored for 32 days. For the most part, it remained near the shoreline between Indian Point and Powderhorn Lake. However, it spent approximately 33% of its time in the southwestern portion of Lavaca Bay. It was last located on 30 August 1996, in Lavaca Bay about 6.5 km to the south southeast of Point Comfort. This turtle was recaptured by Texas A&M researchers on 20 May 1997 adjacent to Sabine Pass, 300 km northeast of its release site.

Kemp's ridley 4391 (subadult female; Fig. 7), released on 30 July 1996 off of Indianola

Beach Park, TX, was monitored for 62 days. It was the second of 6 monitored Kemp's ridleys to enter Lavaca Bay and was found there on 19 of 23 tracking days. Its last recorded position was on 29 September 1996, within a kilometer of shore at the confluence of Lavaca and Matagorda Bays.

Long Range Movements.

A single adult-sized Kemp's (57.0 cm SCL) was fitted with a satellite transmitter on June 26, 1996. For reasons unknown, satellites did not receive data from this tag. Possible explanations for the absence of data include transmitter failure, loss of the transmitter from the animal, or death of the animal. Since this was the only Kemp's ridley fitted with a satellite transmitter, there are no data available from this study in long range (seasonal) movements of Kemp's ridleys into and out of Matagorda Bay.

Study Period Ranges

The home range for all Kemp's ridleys combined was bimodal and included 436.6 km^2 (Fig 8; Table 2). Ninety-five percent of their time was spent in this region. The primary portion of the home range of the Kemp's ridleys extended 1 km northward of the Lavaca Bay Causeway into the vicinity of the discharge site of the Formosa Plastics Plant. It also included all of Cox and Keller Bays, as well as most of Powderhorn Lake, Carancahua and West Matagorda Bays. An isolated part of the home range of Kemp's ridleys was in Tres Palacious Bay. Based on several known locations of Kemp's ridleys, our home range program predicted additional areas that these turtles may inhabit. Thus, the home range of Kemp's ridleys can extend north of the Highway 35 Lavaca Bay Bridge, even though we did not track the turtles in that region of Lavaca Bay. The core area for Kemp's ridley sea turtles, 138.0 km^2, was 32% of the home range. These turtles spent 64% of their time in approximately one-third of their home range. Sufficient data were collected on Kemp's ridleys 5601 and 4391 to determine individual home ranges and core areas (Figs. 3 & 7;

Table 2). Home range and core area for Kemp's ridley 5601 was 35.1 and 11.8 km^2, and it spent 58% of its time in 34% of its home range. Home range and core area were 37.0 and 15.4 km^2 for Kemp's ridley 4391; it spent 60 percent of its time in 42% of its home range. High utilization of a small portion of the home range is indicative of habitat preference, whether it is due to food availability, water temperature, or protection from currents. Care should be taken in interpreting these results, since the data sets for utilization distribution analysis were small.

Submergence Behavior.

Submergence durations of Kemp's ridley turtles ranged from 2.0 sec to 39.9 min with a mean of 6.3 $\pm$ 0.2 min (n = 861). Overall mean submergence durations varied from 3.6-13.9 min for individual turtles (Table 3). Examination of submergence times, by turtle, revealed that 50-90% of submergences were < 10 min and between 8 and 37% were < 1 min (Table 4). Overall submergence time for individual radio-tracked Kemp's ridley turtles was between 91.2% and 95.4%; 92.9% for all Kemp's combined (Table 5). Submergence data were not available for turtles tracked with satellite telemetry. Insufficient data for individual turtles precluded seasonal analyses.

Surface Behavior.

Surface durations of Kemp's ridley turtles ranged from 1.0 sec to 6.2 min. Mean surface duration was 27.4 $\pm$ 0.2 sec (n = 925). Overall mean surface durations varied from 21.5-39.1 sec for individual turtles (Table 3). A breakdown of surface times, by turtle, revealed that 12-65% of their surfacings were < 15 sec and 0-28% were < 5 sec (Table 6). The percent surface time for individual radio-tracked Kemp's ridley turtles was between 4.6% and 8.8%; 7.1% for all Kemp's combined (Table 5). For this particular study, surface data were not available for turtles tracked with satellite telemetry. Insufficient data from individual turtles precluded seasonal analyses.

Green Sea Turtles

Short Range Movements.

Green turtles were fitted with radio and sonic tags to monitor their short-term movements. They remained within 3 km of a 10 km stretch of coast along the west side of Matagorda Bay, from Indian Point in the north to 3 km south of Powderhorn Lake.

Green 5201 (subadult male; Fig. 9), released on 20 June, 1996 near Indian Point, TX, was monitored over 43 days. For the most part, it remained near the shoreline between Indian Point and Powderhorn Lake. It entered the Matagorda Ship Channel on three occasions and spent eight days in the southern reaches of Lavaca Bay. It was last located on 1 August 1996, approximately 500 m south of its release point. Green 4602 (subadult female; Fig. 10), was released on 20 June, 1996 near Indian Point, TX, and monitored over 108 days. It was recaptured on 28 July, retagged, and released a day later. During the first 6 days Green 4602 moved 8 km to the south, and took up residence in a shallow area near the entrance to Powderhorn Lake. From 26 June through 5 November 1996, Green 4602 was located within 50 m of shore along 200 m stretch of shoreline adjacent to the entrance to Powderhorn Lake. It was last observed on 2 October 1996, near the entrance of Powderhorn Lake. Although no further tracking by boat was conducted after 2 October, radio tracking from land confirmed that this turtle remained along this 200 m stretch of coastline through 5 November 1996.

Long Range Seasonal Movements.

Two green turtles captured in late September were released the first week of October 1996. Movement of both turtles increased noticeably with the passage of cold fronts over Matagorda Bay in late November and December. Inshore water temperatures had dropped to 14.9-16.9° C. They began moving back and forth between Matagorda Bay and Espiritu Santo Bay, perhaps in search of warmer water. Green 7299 (Fig. 11) moved between Matagorda Bay, Espiritu Santo Bay, and the Gulf of Mexico (just outside of Matagorda Bay) until 1 January 1997 when it moved offshore of the Texas coast for good. By 6 February 1997 Green 7299 had moved approximately 260 km and was about 40 km south of Port Mansfield in water depths of less than 10 fm. By 3 March 1997 Green 7299 had moved 90 km back to the north in waters offshore of the Texas Laguna Madre. Green 7299 was first located back in Matagorda Bay, on 2 April 1997. Water temperature in Matagorda Bay was not available from satellite imagery maps due to heavy cloud cover over that area in April. However, on 24 March 1997, water temperature in Espiritu Santo Bay had already risen to 22.4° C. Between its departure and return to Matagorda Bay, Green 7299 was in offshore water temperatures varying from 13.1-21.4° C (mean = 17.1°C). Since its return to inshore waters in March 1997, Green 7299 has remained in inshore waters and moved toward Corpus Christi, TX. The last recorded position of this turtle was in Aransas Bay on 11 June 1997.

Green 8009 found its way offshore of Matagorda Bay on 18 December 1996 when Bay water was 16.9° C (Fig. 12). It was in water depths between 10 and 20 fathoms just south of Corpus Christi Bay by 10 January 1997. By 17 January it was an additional 200 km to the south, in the same depth zone, but now in Mexican waters just below the Texas-Mexico border. Green 8009 travelled another 70 km to the south when signals from its transmitter ceased on 30 January 1997. It frequented areas offshore with water temperatures between 13.7 and 23.4° C (mean = 17.8°C).

Study Period Ranges

The home range for both radio-tracked green turtles combined was 19.5 km^2 (Fig 13; Table 2). Ninety-five percent of their time was spent in this region. The area extended approximately 10 km along the western side of Matagorda Bay from Indian Point to 3 km south of Indianola, shoreward of the Matagorda Ship Channel. The core area was 3.4 km^2, or 17% of the home range.   Fifty-three percent of their time was spent in approximately one-fifth of their home range.

Sufficient data were collected on Green 4602 to determine its individual home range and core area (Figs. 10; Table 2). Home range and core area for Green 4602 was 8.1 and 1.8 km^2, respectively. It spent 64% of its time in 22% of its home range. High utilization of a small portion of the home range is indicative of habitat preference, whether it is due to food availability, water temperature, protection from currents. Care should be taken in interpreting these results, since the data sets for utilization distribution analysis were small.

Submergence Behavior.

Intervals of submergence of green turtles ranged from 2.0 sec to 24.3 min with a mean of 1.8 $\pm$ 0.08 min (n = 847). Overall mean submergence durations varied from 1.6-6.4 min for individual turtles (Table 3). A breakdown of submergence times, by turtle, revealed that 75-99% of their submergences were < 10 min and 19-54% were < 1 min (Table 4). The percent of time spent under the water for the two radio-tracked green turtles was 93.2% and 96.2%, 96.1% in combination (Table 5). Submergence data were not available for turtles tracked with satellite telemetry.   Insufficient data from individual turtles precluded analyses of seasonal differences in submergence behavior.

Surface Behavior.

Intervals of time spent on the surface for green turtles ranged from 1.0 sec to 1.3 min with a mean of 4.7 $\pm$ 0.2 sec (n = 881). Overall mean surface durations varied from 3.8-27.6 sec for individual turtles (Table 3). A breakdown of surface times, by turtle revealed that 34-98% of surfacings were < 20 sec and 14-88% were < 5 sec (Table 6). The percent of time spent on the surface for the two radio-tracked green turtles was 3.8% and 6.8%; and 3.9% in combination (Table

5). Surface data were not available for turtles tracked with satellite telemetry. Insufficient data from individual turtles precluded analyses of seasonal differences in submergence behavior.

Environmental Data.

Ranges of measured environmental parameters from 28 May through 5 November 1996 were as follows: 1) air temperature, 22-35° C, 2) water temperature, 22-32° C , 3) salinity, 0-25 parts per thousand, 4) sea state, 0-1 m wave height, 5) wind speed, 0-37 km/h, and 6) cloud cover, 5-100% (Table 7). Variability in mean values of these parameters, by month, was minimal with most changes occurring in September, October and November (Figs. 14 and 15). Highest temperatures occurred in June, with lowest temperatures in September. A salinity of zero was measured in Tres Palacios Bay when tracking Kemp's ridley 4191. During this study, the winds were out of the southeast to southwest 77% of the time. Rougher water conditions occurred when wind came from a northerly or easterly direction (20% of the time), usually just prior to the onset of stormy weather. Since turtles did not move into the northern part of Lavaca Bay, no environmental data were collected near the Formosa Plastics discharge site. These environmental data (Table 7) lack robustness needed for seasonal statistical analyses. Therefore, seasonal trends are apparent only through visual interpretation of the data (Figs. 14 and 15).

DISCUSSION

Prior to 1980, most information concerning sea turtles centered around nesting beaches (number of nesters, clutch sizes, hatching success, predation on nests, and mark-recapture studies on nesting females). These types of data still comprise the vast majority of information on sea turtles. More recently, with the advent of specialized telemetric devices such as radio, sonic and satellite transmitters, knowledge of real-time movements of sea turtles has increased remarkably. A particular focus of electronic tracking has been on understanding movements of juveniles and adults of the world's most endangered sea turtle, the Kemp's ridley. Using satellite telemetry on the Atlantic and southeast coast of the U.S., Renaud (1995) has documented both the movement of Kemp's into the Gulf Stream, and its seasonal movement from north to south during winter months. Similarly, Gitschlag (1996), using both satellite and radio telemetry, has tracked Kemp's ridleys from Georgia to the east coast of Florida in the winter.

In the Gulf of Mexico, Renaud et al. (1995) has satellite-tracked adult Kemp's ridleys up to 2600 km from their release site to other areas of the Gulf. In one instance, an adult female captured in Louisiana during August was followed through the winter, to its nesting beach at Rancho Nuevo, Mexico during the spring of the following year (Renaud et al., 1996). The turtle nested on 23 April 1995 and 19 May 1995. This was the first documented real-time tracking event of a Kemp's ridley onto its nesting beach. Moreover, using radio and satellite telemetry, Renaud et al. (1993, 1994, 1995) has described movements of 85 Kemp's ridley and loggerhead sea turtles released in Texas and Louisiana. Most of these turtles have remained in Texas and Louisiana waters; however, four swam along the northern Gulf shoreline eastward to the Florida Keys (overwintering in each case). One of these sub-adult Kemp's ridleys (53.8 cm SCL) moved from waters off Cameron, Louisiana into the Atlantic Ocean and travelled north along the Florida coast to Sebastian Inlet before returning to the Florida Keys and possibly back into the Gulf of Mexico. Renaud and Carpenter (1994) have monitored the movements of loggerhead turtles for periods up to 10.5 months. They have described home ranges and core areas and calculated mean submergence times, surface-submergence ratios, and swimming speeds for each turtle. Where possible, seasonal variability of surface and submergence activities was addressed. Likewise, Renaud et al. (1995) have intensively monitored the movements of green and loggerhead turtles in the Brazos-Santiago ship Channel and the lower Laguna Madre at the tip of south Texas for up to 5 months. This work led to a detailed description of habitat-related home ranges, day-time foraging areas, night time sleeping areas, surface and submergence intervals and surface to submergence ratios. Several others have made noteworthy contributions in the development of telemetric systems or the gathering of prototype information using telemetric devices to study of sea turtles. Byles (1988) achieved status as one of the pioneers of telemetric work with sea turtles with his involvement in the development, design and miniaturizing of submersible radio and satellite transmitters. Balazs (1994) tracked adult green turtles from nesting grounds at French Frigate Shoals (Leeward Hawaiian Islands) to previously unknown foraging areas in Kaneohe Bay, Oahu, Hawaii and Johnston Atoll. Beavers and Cassano (1996) have used satellite telemetry to define the first detailed studies on surface and submergence behavior, diving behavior, swimming speeds, and day-night differences in activities of the olive ridley (*Lepidochelys olivacea*). Plotkin et al. (1995) used satellite telemetry to study social interactions between female olive ridleys during the internesting period at Nancite, Costa Rica. Standora et. al. (1979, 1984) have used sonic tags with temperature sensors to monitor body temperature of green turtles in Costa Rica and a leatherback turtle off Rhode Island.

Sea Turtle Movements

Seasonal Occurrence.

Estuarine habitat utilization by sea turtles varies with season in all Texas waters, from the lower Laguna Madre on the lower coast to the Galveston Bay on the upper coast, and at Sabine Pass at the Louisiana border (Landry et al., 1994, 1995). Most sea turtles, including greens, loggerheads, and Kemp's ridleys, arrive in April and May and depart in October and November, depending on the onset of winter weather and lower water temperatures. In south Texas, near Brazos-Santiago Pass, water temperatures may not decrease enough in the fall months to flush the sea turtles out of the lower Texas Laguna Madre[4]. Thus, turtles may overwinter in lower Texas estuaries.

Sea turtles in our study of Matagorda and Lavaca Bays followed the pattern of estuarine habitat utilization exhibited by turtles of the upper Texas coast (Landry et al., 1994, 1995). We tracked greens by radio-sonic telemetry in the summer from 20 June 1996 through the warm initial part of the fall, until 2 October 1996. Two green turtles, captured in October 1996, were monitored with satellite telemetry from three to 7 months. They exhibited increased movements in November and December, during subsequent cooling of bay waters after the passage of cold fronts. Bay water temperatures dropped from monthly summer means near 30° C to less than 17° C by November and December. These green sea turtles appeared to have begun seeking warmer water during these months. These greens moved into the Gulf of Mexico on 18 December 1996 (Green 8009) and 1 January 1997 (Green 7299). At that time they relocated in offshore waters where temperatures were 13-19° C and moved in a southerly direction along the coast. Green 7299 returned to Matagorda Bay in March 1997 and has since been in inshore waters. In an earlier study, a satellite-tracked Kemp's ridley sea turtle released at Sabine Pass, TX, overwintered offshore and returned to an inshore nursery area, Matagorda Bay, the following spring (Renaud et. al., 1995).

It is presumed that the radio-tracked turtles left Matagorda Bay during the same period as the satellite-tracked turtles. Kemp's ridley 5801, tracked for 32 days in Matagorda and Lavaca

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[4]Personal Communication: Dr. Andy Landry, Texas A&M University, 4700 Avenue U, Galveston, TX. 77551

Bays, was recaptured in the spring of 1997 near the Sabine Pass jetties, a known nursery area for Kemp's ridley sea turtles (Landry et al., 1994, 1995). These types of movements for both green and Kemp's ridley sea turtles suggest that they are not restricted locally, but are part of a far-reaching larger population of animals, with roughly similar migratory behavior.

During a previous study in Matagorda Bay in 1995, two green turtles (4.8 and 11.0 kg) were tagged and released, one near on the north shore Decros Point on Matagorda Peninsula and one at the east end of Matagorda Island (Renaud, Unpublished Data). Using satellite telemetry, those turtles were monitored in August, September and October, for periods of 25 and 49 days. Like the greens in our current study, those turtles utilized grassbeds near their capture sites and frequented areas in the Gulf of Mexico near the entrance to Cavallo Pass, Texas before moving offshore and south in the Gulf of Mexico during the onset of cool weather in September and October of 1995.

Movement away from cooler water in the fall and early winter has been documented for green turtles at South Padre Island (Renaud et al., 1993, 1995) and Matagorda Bay (Renaud, Unpublished Data), and for loggerhead (Renaud and Carpenter, 1994) and Kemp's ridley (Renaud, 1995) turtles in coastal waters of the Gulf of Mexico. This body of tracking data suggests that an abrupt decrease in water temperature stimulates all sea turtles to move out of the upper and middle Texas coastal bays and estuaries during winter months. Those few that remain risk being affected during sudden onset of severe cold weather. Accordingly, cold stunning of Kemp's ridley, green and loggerhead sea turtles in water temperatures below 10° C has been documented in South Texas by Hildebrand (1982) and Shaver (1990). This phenomenon also occurs on the eastern U.S. coast for the same three turtle species: as reported in the Indian River Lagoon System of Florida (Witherington and Ehrhart, 1989) and the Pamlico Sound of North Carolina (Schwartz, 1978). Cold stunning of Kemp's ridleys has been documented in as far north as Long Island Sound, New York (Morreale et al., 1992; Burke et. al., 1991).

Habitat Preferences.

For the most part, the green and Kemp's ridley sea turtles that we observed, stayed within 2.5 km of the shoreline in Matagorda, Lavaca and Tres Palacios Bays in water depths less than three meters. Thus, we believe that these sea turtles normally utilize the shallower parts of the Bay. Occurrence of these turtles within the central, deeper part of Matagorda Bay was rare. One Kemp's ridley crossed the Bay, but reestablished itself in a shallow (<3 m) shoreline area similar in characteristic to regions utilized by other tracked turtles. Kemp's ridley turtles were not tracked nearer than 10 km of the Formosa Plastics discharge site.

The nearshore presence of green turtles corresponded to the presence of their seagrass feeding grounds. Seagrass beds were common on the perimeter of Matagorda Bay, and sparse if not nonexistent deep water areas and Lavaca Bay. Green turtles were tracked not nearer than 15 km of the Formosa Plastics discharge site. This distribution pattern was similar to that found for 9 green turtles (29-48 cm SCL) monitored at Brazos-Santiago Pass and in the Texas Lower Laguna Madre by Renaud et. al. (1995). Generally, those turtles also remained in water depths <3 m, near the jetties at Brazos-Santiago Pass or in shallow sea grass beds in the Laguna Madre.

Green and Kemp's ridleys sea turtles occurred infrequently in the deep water of Matagorda (12 m depths) and Lavaca Ship (4 m depths) Channels. Kemp's ridleys were documented in the Matagorda Ship Channel on only 7 of 53 (13.2%) tracking days. Green turtles were monitored in the channel on 2 of 40 (5%) days that they were tracked. This also mirrored behavior of green sea turtles studied by Renaud et. al. (1995) at Brazos-Santiago Pass and by Kemp's ridley turtles tracked in the Sabine and Calcasieu Ship Channels (Renaud et. al., 1995). Depths in the Sabine and Calcasieu Channels approached twelve meters.

Abundance.

A separate report prepared by Texas A&M University, Institute of Marine Life Science addresses sea turtle abundance in Lavaca and Matagorda Bays as well as food sources to available sea turtles during May through September 1996. Their preliminary report, submitted in September 1996 to Robert Lawrence, Chief of Office of Planning and Coordination, EPA, Region 6, Dallas, TX, states that "sea turtles do not utilize Lavaca Bay with any known frequency. It is also suggested that low concentrations of blue crab (*Callinectes sapidus*), the major food source of Kemp's ridley sea turtles (Landry et al, 1994, 1995), may be a determining factor in determining the abundance of the Kemp's ridley sea turtles in Matagorda and Lavaca Bays. And finally, the report states that low salinity may have played a role in reducing the concentrations of blue crabs in these Bays. Refer to the Final Report by Texas A&M for updated and more detailed information. Our data on movements suggest that Kemp's ridley sea turtles may be more dispersed in Matagorda and Lavaca Bays than in other areas such as Sabine Pass. This may confound measuring abundance, e.g., affect of concentration at a pass versus dispersion throughout a system.

Satellite Data

Satellite tracking of sea turtles offers a special problems for the scientist. Sea turtles usually spend 90-95% of their time under the oceans surface (Byles, 1989; Renaud and Carpenter, 1994; Renaud, 1995; Renaud et. al., 1995). Since radio signals from the satellite tag do not travel through salt water, the tags are usually programmed to turn off when they are under the water. Regardless, sea turtles are on the sea surface only intermittently, and satellites may not always be in a position to receive their tag transmissions. Subadult turtles, such as those monitored in this study, have much shorter surface intervals than adult turtles (Renaud et al., 1993, 1995). These shorter intervals further reduce the number of transmissions available to a satellite and therefore the number of calculated locations. Satellite tags must transmit 4 times over a 7 minute period to obtain accurate location data. The number of transmissions generally determines the accuracy of the locations. Most of our locations were based on only 2 or 3 transmissions with a possible error of $\pm$ 1 km. When turtles begin to move around more in the winter (e.g. to search for warmer water) they expend more energy and must be at the surface more often to breathe. As a result, the acquisition of location data increases when turtles are confronted with colder weather. Altered behavior of the turtles in the winter may also include basking at the sea surface. The accuracy of tracking animals with satellite telemetry does not compare with that obtained by radio/sonic tracking, where error was equal to that of the GPS unit. Because of this, satellite tracking is best used for long term monitoring of animals, and to gain information on migration patterns between seasons. Accordingly, we used satellite data to describe seasonal movements of two green turtles in this report.

Surface and Submergence Durations

Characterization of sea turtle submergence and surface patterns helps identify the risk of sea turtles to various activities of man, such as shrimping, dredging, use of explosives in demolition activities, recreational fishing, boating, and shipping, as well as to determine a broad behavior and health index for the turtles. Chemical pollution could affect sea turtles whether or not they are at or below the oceans surface. Submergence times were measured for Kemp's ridley turtles in this study were similar to the mean submergence time of 33 similar sized Kemp's ridleys (7.7 min), observed by Renaud et al. (1994). Mean submergence times for our Kemp's ridley sea turtles were below values reported for larger Kemp's ridleys: 16.7 min by Mendonca and Pritchard (1986) and 33.7 min reported by Renaud (Renaud, NOAA, NMFS, Galveston, TX, Manuscript in preparation). Lower mean submergence times may be due to a lesser lung capacity of these small turtles.

Submergence durations of our green turtles were similar to submergences of green turtles tracked near Brazos-Santiago Pass, TX (Renaud, et. al., 1995). Mean submergence and surface times were notably shorter for Green 4602 than all other tracked turtles. In this case, sea turtle size and habitat depth of Green 4602 probably affected surface and submergence differences as much as interspecfic differences. It spent over ninety percent of its time in water depths less than 1.5 meters. Small vertical movements could lead to more "surfacing events", resulting in shortened bottom times. Being at the surface more often also reduces the need to remain there for extended periods. Green turtle 5201 (7.6 kg) fell into the middle of the size and weight range of the Kemp's ridley turtles. The depth zone it inhabited and its surface and surface durations were similar to those of the Kemp's ridleys.

Being aquatic animals, the physiology of sea turtles adapts them to spend most of their time submerged. Unhealthy or stressed turtles may increase time spent at the surface. In our study, the time spent under water varied between 91.2-95.4% for individual Kemp's ridley sea turtles and between 93.2-96.1% for individual green sea turtles. These values were similar to 33 Kemp's ridleys (Renaud et al. 1994) (71-96%), three juvenile loggerheads (Renaud and Carpenter 1994) (90.0-95.7%), two juvenile Kemp's ridleys (Renaud, 1995) (94.0-98.6%), and 9 greens (Renaud et al. 1993) (80.8-97.8%) monitored at other locations during the same months. Byles (1989), found that adult Kemp's ridleys spent an average 96% of their time submerged. The amount of time our monitored turtles spent submerged and at the surface was used as one measure of normality of sea turtle behavior. Based on similarity to sea turtles in other studies, we conclude that our turtles fell within the range normal behavior for healthy sea turtles.

CONCLUSION

The objective of our research was to evaluate movements of sea turtles in the Lavaca and Matagorda Bays and to describe their association with specific habitats, (i.e., channels, oyster reefs, seagrass beds, and other areas in the bay) and with geographic areas of the bay, especially in the area of the Formosa discharge. We hypothesized that turtles would use all parts of the bay equally. Our data disprove this hypothesis. Data collected during 1996 demonstrated that Kemp's ridleys mostly utilize the shallow areas along the western perimeter of Matagorda and Lavaca Bays. Central and eastern Matagorda Bay and central Lavaca Bay were less frequented by these turtles. Southeastern Matagorda Bay, northern Lavaca Bay, and the upper reaches of Carancahua and Tres Palacios Bays were not utilized by turtles in this study. These latter areas are in the immediate proximity of freshwater river inflow, which may discourage use of areas by sea turtles.

The northern extent of home range for Kemp's ridley sea turtles, during the months of May through October, roughly corresponded to the Highway 35 Bridge and Causeway in Lavaca Bay, included all of Keller Bay and Cox Bay, and major portions of West Matagorda and Carancahua Bays. Green turtles used the southwestern part of Lavaca Bay and the western shores of Matagorda Bay coincident with distribution of seagrass habitats. The home range of Kemp's ridley sea turtles nearly overlaps with the discharge site of Formosa Plastics while the home range of the green turtles falls 10 km short of the discharge site. However, the path that the effluents from the discharge must travel to the Gulf of Mexico traverses the area occupied by these turtles. The spatial overlap of home ranges for both turtle species is downstream of discharge from the Formosa Plastics Plant. However remote, impact on sea turtles cannot be ruled out. For example, physio-chemical changes in water at the discharge site might deter the entrance of sea turtles into an area, or indirectly affect sea turtles by changing the spatial distribution or density of prey items, thereby reducing habitat to sea turtles. Although sea turtles were not tracked closer than 10 km to the discharge site, this does not preclude their use of that area during years with differing conditions.

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Table 1. Measurements and tracking information for seven Kemp's ridley and four green sea turtles tracked in Matagorda Bay, TX.

Turtle Species ID and (Sex)*	Tracking Dates	Days Tracked	Straight Carapace Length (cm)	Weight (kg)
Radio Tags	1996			
Ridley 4191(m)	28 May to 27 Jun	31	33.5	4.8
Ridley 5601(m)	28 May to 01 Aug	66	32.8	5.4
Ridley 5001(f)	22 Jun to 28 Jun	7	34.3	5.1
Ridley 4811(m)	24 Jul to 02 Aug	10	31.5	4.0
Ridley 4391(f)	30 Jul to 29 Sep	62	40.4	8.7
Ridley 5801(f)	31 Jul to 30 Aug	31	43.9	11.1
Green 5201(m)	20 Jun to 01 Aug	43	37.5	7.6
Green 4602(f)	20 Jun to 05 Nov	139	29.9	3.3
Satellite Tags	1996-1997			
Ridley 8001(m)	No Data	0	58.4	21.7
Green 7299(unk)**	Oct 1 to Mar 17	168	36.3	4.6
Green 8009(unk)	Oct 2 to Jan 28	119	35.0	5.5

*The sex of sea turtles was provided Michael Coyne, Texas A&M University, College Station, Texas
** Still tracking

Table 2. Home range area (95% utilization distribution) and core area (percent utilization determined by Home Range Program) to the nearest square kilometer, for of Kemp's ridley and green sea turtles in Lavaca and Matagorda Bays, 28 May through 5 November 1996.

Turtles	Home Range	Core Area	Percent Utilization of Calculated Core Area
Kemp' ridleys	437	138	64 %
Greens	19	3	53 %
Ridley 4391	37	15	60 %
Ridley 5601	35	12	58 %
Green 4602	8	2	64%

Table 3. Submergence and surface durations (in seconds) for all turtles combined, for each species, and for individual sea turtles radio-tracked in 1996.

Submergence Duration

	N Obs	Minimum	Maximum	Mean	Std Dev	Std Error
All turtles combined	1708	2	2394	242.5	341.7	8.3
Kemp' ridleys	861	2	2394	376.7	372.9	12.7
Greens	847	2	1459	106.1	137.0	4.7
Ridley 4191	184	4	2345	450.3	443.1	32.7
Ridley 5601	205	2	1803	492.3	362.9	25.3
Ridley 5001	10	14	1692	604.6	579.5	183.2
Ridley 4811	12	47	1280	833.6	390.8	112.8
Ridley 4391	340	2	1471	213.7	252.2	13.7
Ridley 5801	110	4	2394	471.1	626.5	59.7
Green 5201	32	6	1229	382.4	325.2	57.5
Green 4602	815	2	1459	95.3	129.6	4.5
Green 7299	Data not available from satellite tags					
Green 8009	Data not available from satellite tags					

Surface Duration

	N Obs	Minimum	Maximum	Mean	Std Dev	Std Error
All turtles combined	1806	1.000	371	16.4	26.6	0.6
Kemp's ridleys	925	1	371	27.4	31.5	1.0
Greens	881	1	78	4.7	6.0	0.2
Ridley 4191	195	2	160	32.6	25.3	1.8
Ridley 5601	222	2	128	28.9	21.5	1.4
Ridley 5001	11	11	75	36.8	24.5	7.4
Ridley 4811	17	3	75	39.1	22.7	5.5
Ridley 4391	359	1	371	21.5	39.3	2.1
Ridley 5801	121	1	317	31.2	38.4	3.5
Green 5201	35	2	72	27.6	18.55	3.1
Green 4602	846	1	78	3.8	5.4	0.2
Green 7299	Data not available from satellite tags					
Green 8009	Data not available from satellite tags					

Table 4. Frequency of submergence durations, by time category, for all turtles combined, for each species and for individual turtles radio-tracked in 1996.

All Turtles — Frequency of submergence seconds (plsub)

Plsub	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0-1	667	39.1	667	39.1
1-10	841	49.2	1508	88.3
10-20	150	8.8	1658	97.1
20-30	37	2.2	1695	99.2
30-40	13	0.8	1708	100.0
	1708			

Kemp's Ridleys — Frequency of submergence seconds (plsub)

Plsub	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0-1	219	25.4	219	25.4
1-10	457	53.1	676	78.5
10-20	139	16.1	815	94.6
20-30	33	3.8	848	98.4
30-40	13	1.6	861	100.0
	861			

Greens — Frequency of submergence seconds (plsub)

Plsub	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0-1	448	52.9	448	52.9
1-10	384	45.3	832	98.2
10-20	11	1.3	843	99.5
20-30	4	0.5	847	100.0
30-40	0	0.0	847	100.0
	847			

Ridley 4191 — Frequency of submergence seconds (plsub)

```
Plsub                                         Cum              Cum
                                        Freq  Freq  Percent  Percent
 0-1    |****                             20    20    10.87    10.87
 1-10   |************************ 121   141    65.76    76.63
10-20   |*****                            27   168    14.67    91.30
20-30   |***                              13   181     7.07    98.37
30-40   |*                                 3   184     1.63   100.00
        --------+-------+-------+
                40      80     120
                Frequency
```

Ridley 5601 — Frequency of submergence seconds (plsub)

```
Plsub                                                          Cum
Cum
                                          Freq  Freq  Percent  Percent
 0-1    |************                       29    29    14.15    14.15
 1-10   |********************************* 110   139    53.66    67.80
10-20   |***********************            57   196    27.80    95.61
20-30   |***                                 8   204     3.90    99.51
30-40   |                                    1   205     0.49   100.00
        --------+-------+-------+-------+-------+----
                20      40      60      80     100
                          Frequency
```

```
Ridley 5001       Frequency of submergence seconds (plsub)
              Plsub                                                    Cum                 Cum
                                                                Freq  Freq  Percent  Percent
               0-1     |******************************           3     3    30.00    30.00
               1-10    |********************                     2     5    20.00    50.00
              10-20    |****************************************  4     9    40.00    90.00
              20-30    |**********                               1    10    10.00   100.00
                       ----------+---------+---------+---------+
                                 1         2         3         4
                                         Frequency
```

```
Ridley 4811       Frequency of submergence seconds (plsub)
              Plsub                                     Cum                 Cum
                                                 Freq  Freq  Percent  Percent
               0-1     |*****                       1     1     8.33     8.33
               1-10    |***************             3     4    25.00    33.33
              10-20    |*************************   5     9    41.67    75.00
              20-30    |***************             3    12    25.00   100.00
                       -----+----+----+----+----+
                            1    2    3    4    5
                                Frequency
```

```
Ridley 4391       Frequency of submergence seconds (plsub)
              Plsub                                                Cum                 Cum
                                                            Freq  Freq  Percent  Percent
               0-1     |*************************             127   127    37.35    37.35
               1-10    |************************************  179   306    52.65    90.00
              10-20    |*******                                33   339     9.71    99.71
              20-30    |                                        1   340     0.29   100.00
                       --------+-------+-------+-------+----
                              40      80      120     160
                                     Frequency
```

```
Ridley 5801       Frequency of submergence seconds (plsub)
              Plsub                                                Cum                Cum
                                                             Freq  Freq  Percent  Percent
               0-1     |*********************************     39    39    35.45    35.45
               1-10    |************************************  42    81    38.18    73.64
              10-20    |*************                         13    94    11.82    85.45
              20-30    |*******                                7   101     6.36    91.82
              30-40    |*********                              9   110     8.18   100.00
                       -----+----+----+----+----+----+----+----+--
                            5   10   15   20   25   30   35   40
                                      Frequency
```

```
Green 5201        Frequency of submergence seconds (plsub)
              Plsub                                                Cum                 Cum
                                                            Freq  Freq  Percent  Percent
               0-1     |************                          6     6    18.75    18.75
               1-10    |************************************ 18    24    56.25    75.00
              10-20    |**************                        7    31    21.87    96.87
              20-30    |**                                    1    32     3.12   100.00
                       ----+---+---+---+---+---+---+---+---+
                           2   4   6   8   10  12  14  16  18
                                     Frequency
```

```
Green 4602        Frequency of submergence seconds (plsub)
              Plsub                                              Cum                 Cum
                                                           Freq  Freq  Percent  Percent
               0-1    |************************************** 442   442    54.23    54.23
               1-10   |*******************************        366   808    44.91    99.14
              10-20   |                                         4   812     0.49    99.63
              20-30   |                                         3   815     0.37   100.00
                      -----+----+----+----+----+----+----+----+----
                           50  100  150  200  250  300  350  400
                                         Frequency
```

Table 5. Time spent submerged and at the surface for all turtles combined, for each species, and for individual turtles radio-tracked in 1996.

Turtles	Percent	
	Submerged	Surfaced
All turtles combined	93.4	6.6
Kemp' ridleys	92.9	7.1
Greens	96.1	3.9
Ridley 4191	93.3	6.7
Ridley 5601	94.6	5.4
Ridley 5001	94.7	5.3
Ridley 4811	95.4	4.6
Ridley 4391	91.2	8.8
Ridley 5801	93.9	6.1
Green 5201	93.2	6.8
Green 4602	96.2	3.8
Green 7299	Data not available from satellite tags	
Green 8009	Data not available from satellite tags	

Table 6. Frequency of surface durations by second categories for all turtles combined, for each species and for individual turtles radio-tracked in 1996.

All Turtles — Frequency of surface seconds (plsub)

PLSURF	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0-5	905	50.1	905	50.1
5-15	371	20.5	1276	70.7
15-30	195	10.8	1471	81.5
30-60	246	13.6	1717	95.1
60+	89	4.9	1806	100.0
	1806			

Kemp's Ridleys — Frequency of surface seconds (plsub)

Plsub	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0-1	152	16.4	152	16.4
1-10	281	30.4	433	46.8
10-20	182	19.7	615	66.5
20-30	224	24.2	839	90.7
30-40	86	9.3	925	100.0
	925			

Greens — Frequency of surface seconds (plsub)

Plsub	Frequency	Percent	Cumulative Frequency	Cumulative Percent
0-1	753	85.5	753	85.5
1-10	90	10.2	843	95.7
10-20	13	1.5	856	97.2
20-30	22	2.5	878	99.7
30-40	3	0.3	881	100.0
	881			

Ridley 4191 — Frequency of surface seconds (plsub)

```
Plsurf                                                      Cum             Cum
                                                      Freq  Freq  Percent  Percent
 0-5    |******                                         12    12     6.15     6.15
 5-15   |************************                       47    59    24.10    30.26
15-30   |*********************                          41   100    21.03    51.28
30-60   |*************************************          73   173    37.44    88.72
60+     |***********                                    22   195    11.28   100.00
        -----+----+----+----+----+----+----+--
            10   20   30   40   50   60   70
                      Frequency
```

Ridley 5601 — Frequency of surface seconds (plsub)

```
Plsurf                                                          Cum             Cum
                                                          Freq  Freq  Percent  Percent
 0-5    |*********                                          18    18     8.11     8.11
 5-15   |****************************                       56    74    25.23    33.33
15-30   |***************************                        53   127    23.87    57.21
30-60   |*****************************************          81   208    36.49    93.69
60+     |*******                                            14   222     6.31   100.00
        -----+----+----+----+----+----+----+----+-
            10   20   30   40   50   60   70   80
                        Frequency
```

```
Ridley 5001      Frequency of surface seconds (plsub)
            Plsurf                                                Cum                 Cum
                                                           Freq  Freq   Percent  Percent
             5-15     |******************************   3     3     27.27    27.27
            15-30     |******************************   3     6     27.27    54.55
            30-60     |******************************   3     9     27.27    81.82
            60+       |********************             2    11     18.18   100.00
                      ----------+---------+---------+
                               1         2         3
                                Frequency
```

```
Ridley 4811      Frequency of surface seconds (plsub)
            Plsurf                                                Cum                 Cum
                                                           Freq  Freq   Percent  Percent
             0-5      |*****                            1     1      5.88     5.88
             5-15     |*****                            1     2      5.88    11.76
            15-30     |******************************   6     8     35.29    47.06
            30-60     |*************************        5    13     29.41    76.47
            60+       |********************             4    17     23.53   100.00
                      -----+----+----+----+----+----+
                          1    2    3    4    5    6
                                Frequency
```

```
Ridley 44391     Frequency of surface seconds (plsub)
            Plsurf                                             Cum                 Cum
                                                        Freq  Freq   Percent  Percent
             0-5      |********************          99    99    27.5827.58
             5-15     |*************************** 135   234    37.6065.18
            15-30     |************                  60   294    16.71    81.89
            30-60     |********                      41   335    11.42    93.31
            60+       |*****                         24   359     6.69   100.00
                      --------+-------+-------+---
                             40      80     120
                               Frequency
```

```
Ridley 5801      Frequency of surface seconds (plsub)
            Plsurf                                                        Cum                 Cum
                                                                   Freq  Freq   Percent  Percent
             0-5      |**********************                  22    22     18.18    18.18
             5-15     |*************************************** 39    61     32.23    50.41
            15-30     |*******************                     19    80     15.70    66.12
            30-60     |*********************                   21   101     17.36    83.47
            60+       |********************                    20   121     16.53   100.00
                      -----+----+----+----+----+----+----+----
                          5   10   15   20   25   30   35
                                     Frequency
```

```
Green 5201       Frequency of surface seconds (plsub)
            Plsurf                                                  Cum                 Cum
                                                             Freq  Freq   Percent  Percent
             0-5      |**********                           5     5     14.29    14.29
             5-15     |**************                       7    12     20.00    34.29
            15-30     |************                         6    18     17.14    51.43
            30-60     |******************************** 16    34     45.71    97.14
            60+       |**                                   1    35      2.86   100.00
                      ----+---+---+---+---+---+---+---+
                         2   4   6   8   10  12  14  16
                                 Frequency
```

```
Green 4602        Frequency of surface seconds (plsub)
            Plsurf                                                      Cum                  Cum
                                                                 Freq   Freq   Percent   Percent
             0-5      |*************************************  748    748     88.42     88.42
             5-15     |****                                     83    831      9.81     98.23
            15-30     |                                          7    838      0.83     99.05
            30-60     |                                          6    844      0.71     99.76
            60+       |                                          2    846      0.24    100.00
                      -----+----+----+----+----+----+----+--
                          100  200  300  400  500  600  700
                                     Frequency
```

Table 7. Measurements of air and water temperature, surface water salinity, cloud cover, sea state, wind speed and direction in Matagorda and Lavaca Bays from May 28 to November 5, 1996.

N Obs	Variable	N	Minimum	Maximum	Mean	Std Dev
96	AIR	96	22.0	35.0	30.2	1.9
	WATER	96	22.0	32.0	29.3	1.5
	SAL_PPT	96	0.00	25.0	19.1	4.6
	CLOUD	96	5.0	100.0	60.8	25.4
	SEA_FT	96	0.0	3.0	1.3	0.7
	WIND	96	0.0	23.0	10.0	5.4

WIND DIRECTION	Freq	Percent	Cumulative Frequency	Cumulative Percent
unknown	4	4.2	4	4.2
E	8	8.3	12	12.5
ENE	1	1.0	13	13.5
ESE	1	1.0	14	14.6
NNE	5	5.2	19	19.8
S	16	16.7	35	36.5
SE	29	30.2	64	66.7
SSE	17	17.7	81	84.4
SSW	7	7.3	88	91.7
SW	5	5.2	93	96.9
WSW	3	3.1	96	100.0

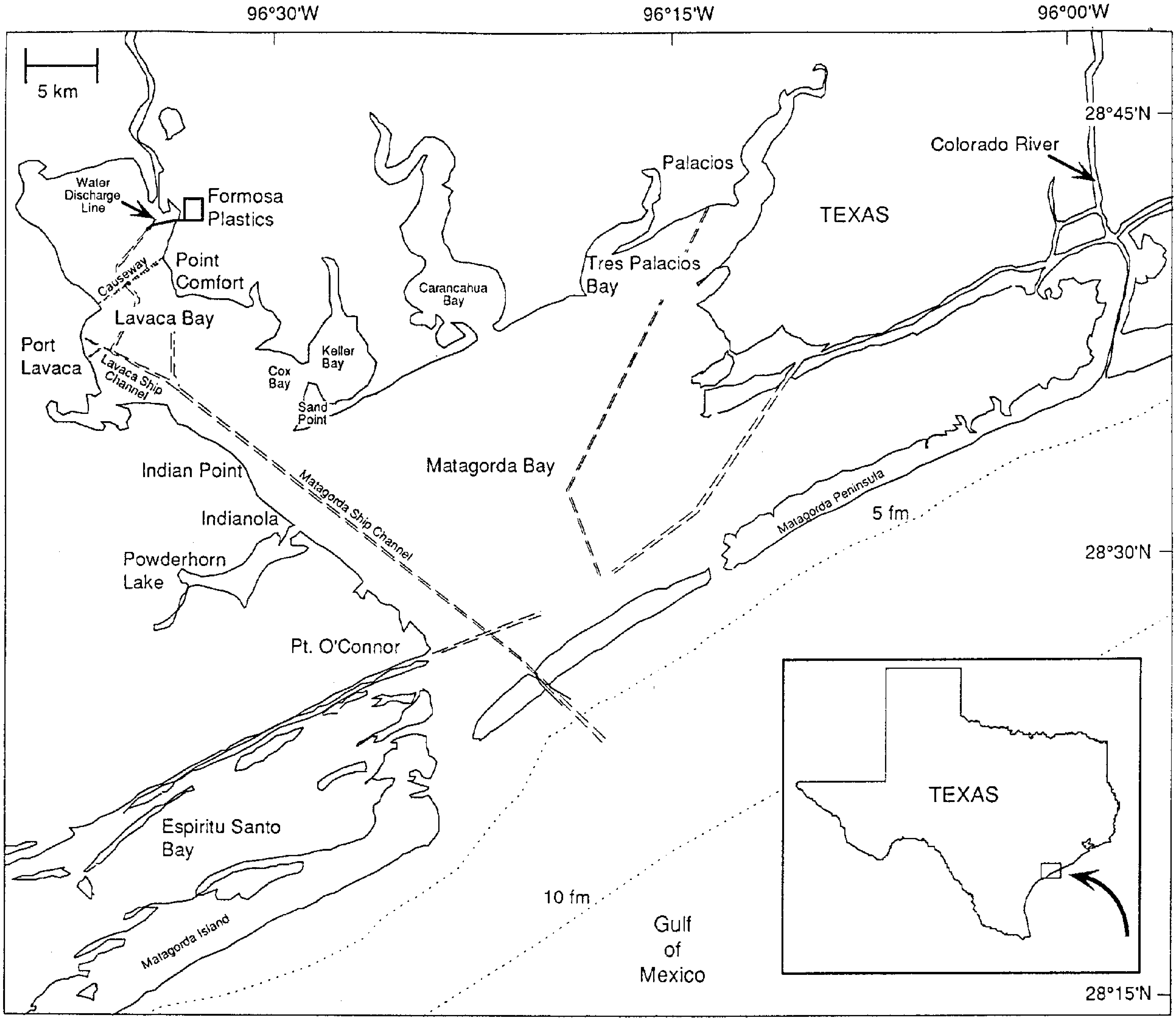

Figure 1. Study area encompassing Lavaca Bay and West Matagorda Bay.

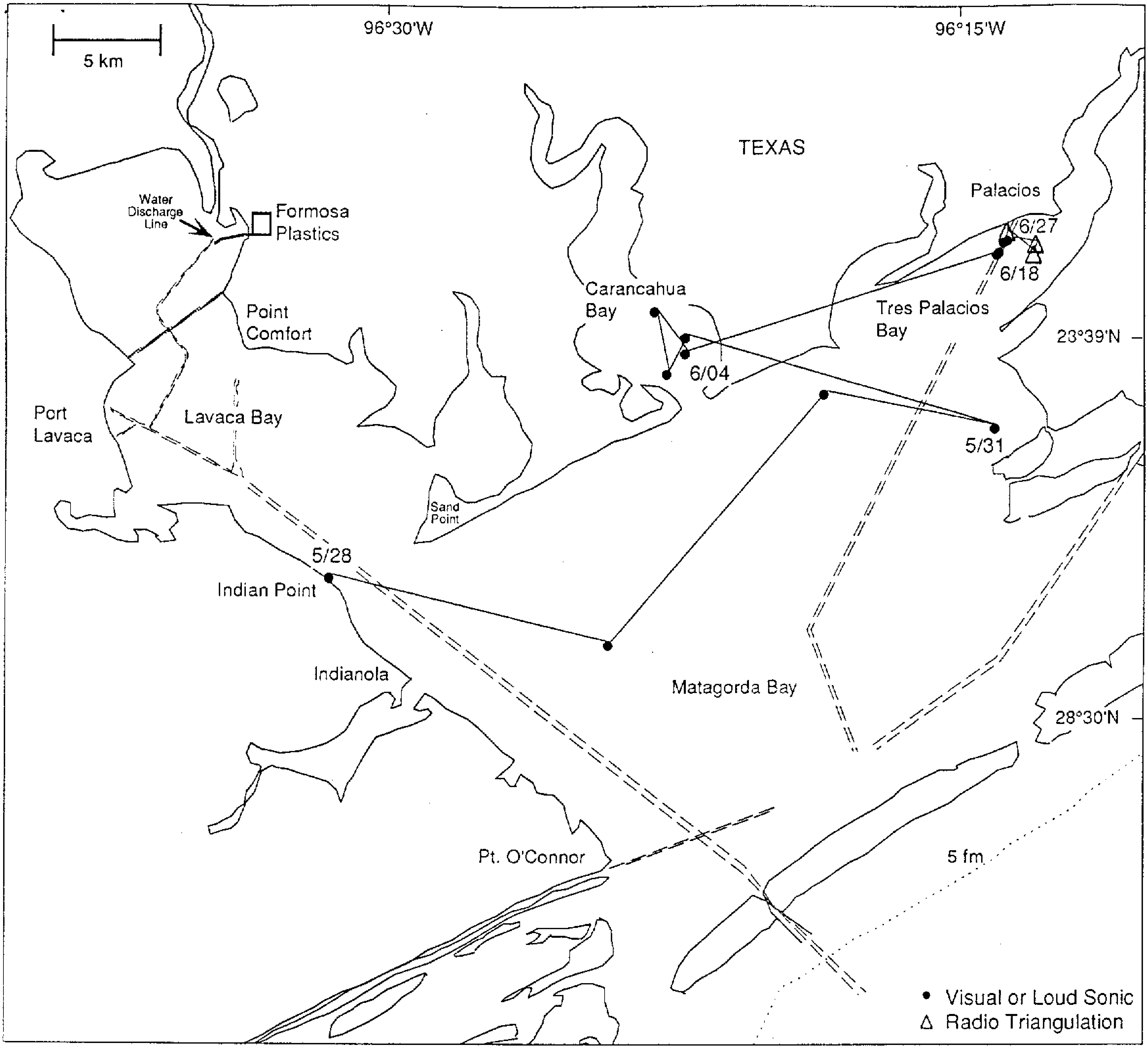

Figure 2. Movements of radio-tracked subadult male Kemp's ridley sea turtle 4191 (33.5 cm SCL) from 28 May - 27 June 1996.

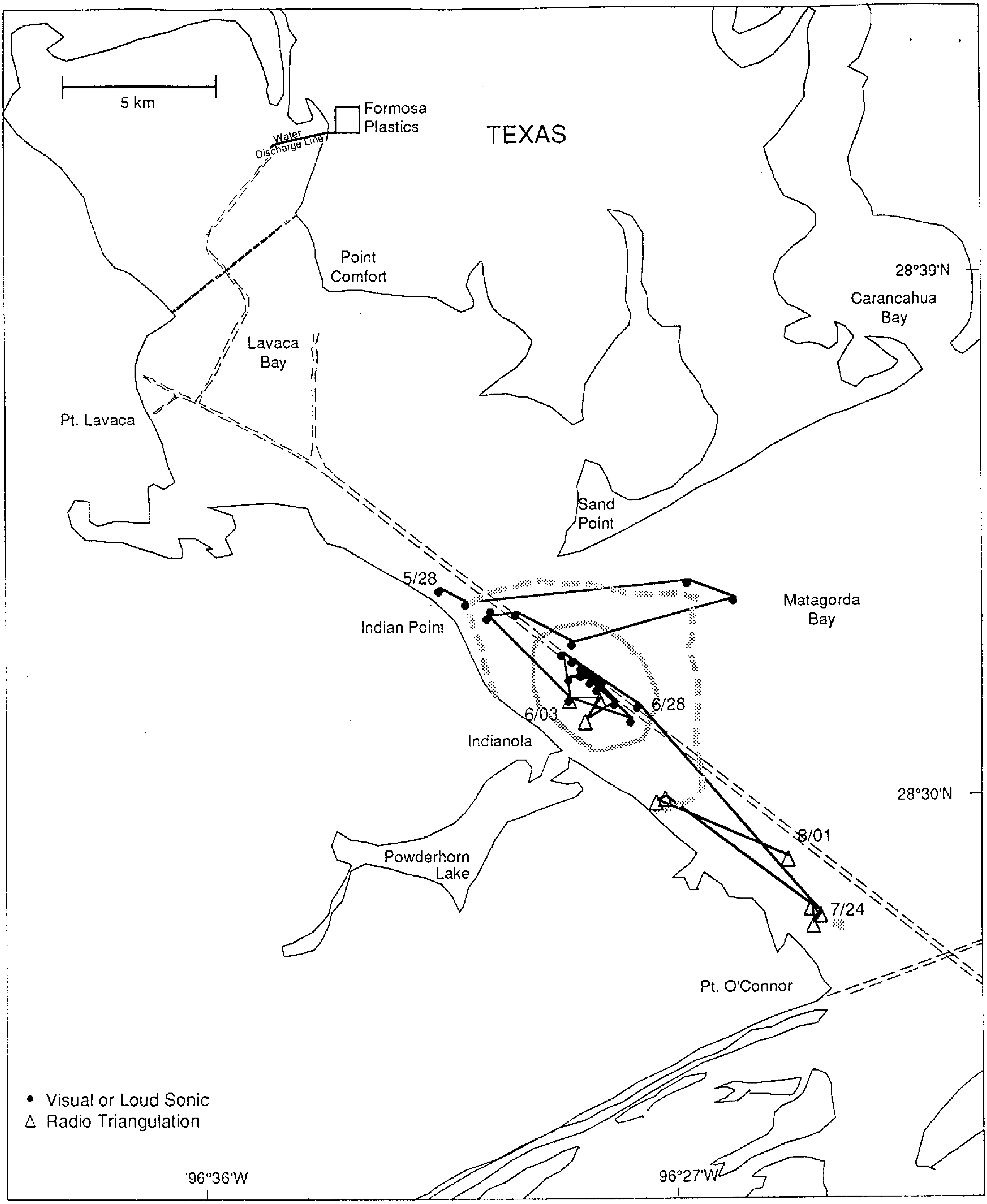

Figure 3. Movements of radio-tracked subadult male Kemp's ridley sea turtle 5601 (32.8 cm SCL) from 28 May - 1 August 1996. Home range (95% utilization distribution) is outlined with a dotted line and core area (58% utilization distribution) is outlined with a solid line.

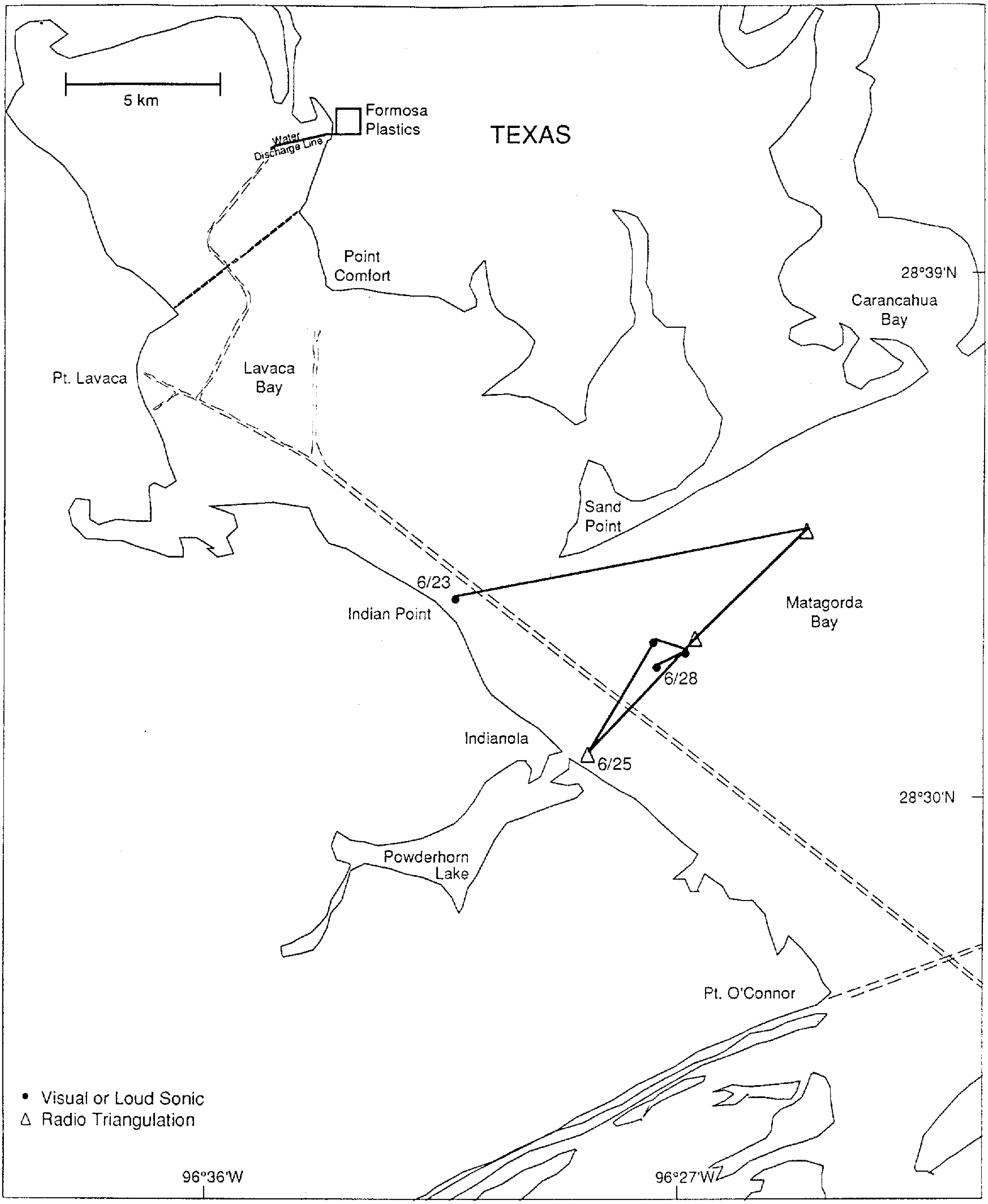

Figure 4. Movements of radio-tracked subadult female Kemp's ridley sea turtle 5001 (34.3 cm SCL) from 22 - 28 June 1996.

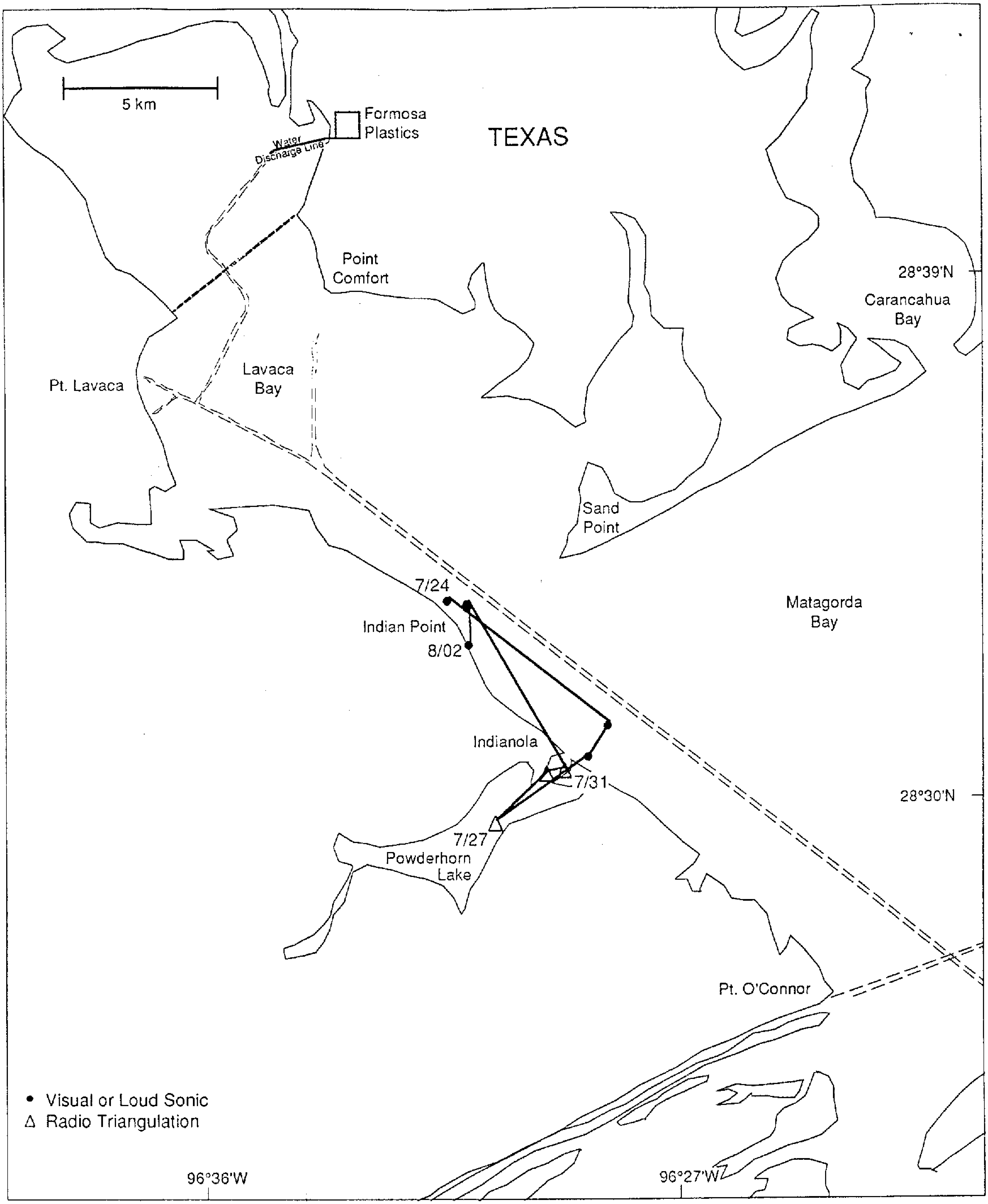

Figure 5. Movements of radio-tracked subadult male Kemp's ridley sea turtle 4811 (31.5 cm SCL) from 24 July - 2 August 1996.

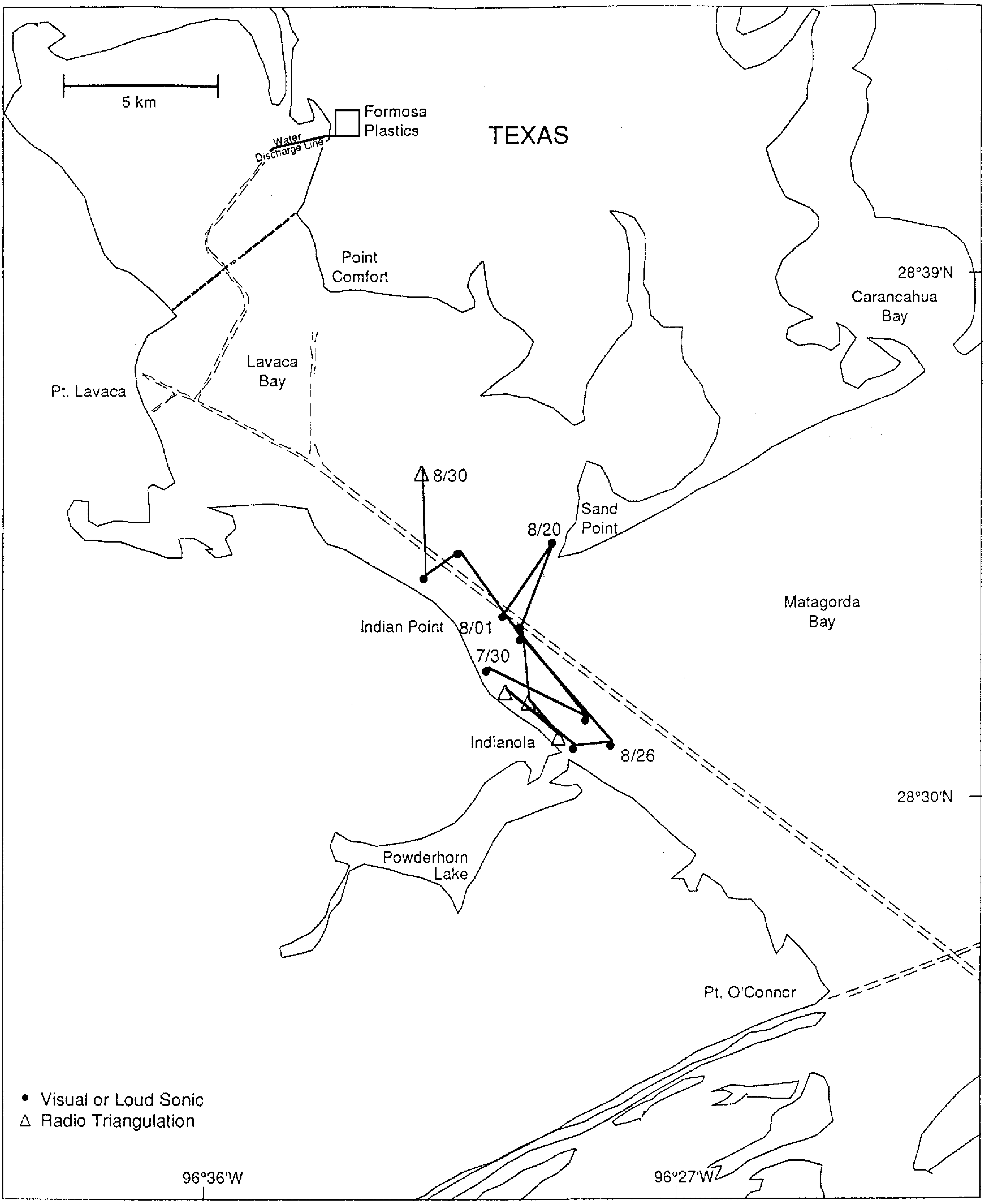

Figure 6. Movements of radio-tracked subadult female Kemp's ridley sea turtle 5801 (43.9 cm SCL) from 30 July - 30 August 1996.

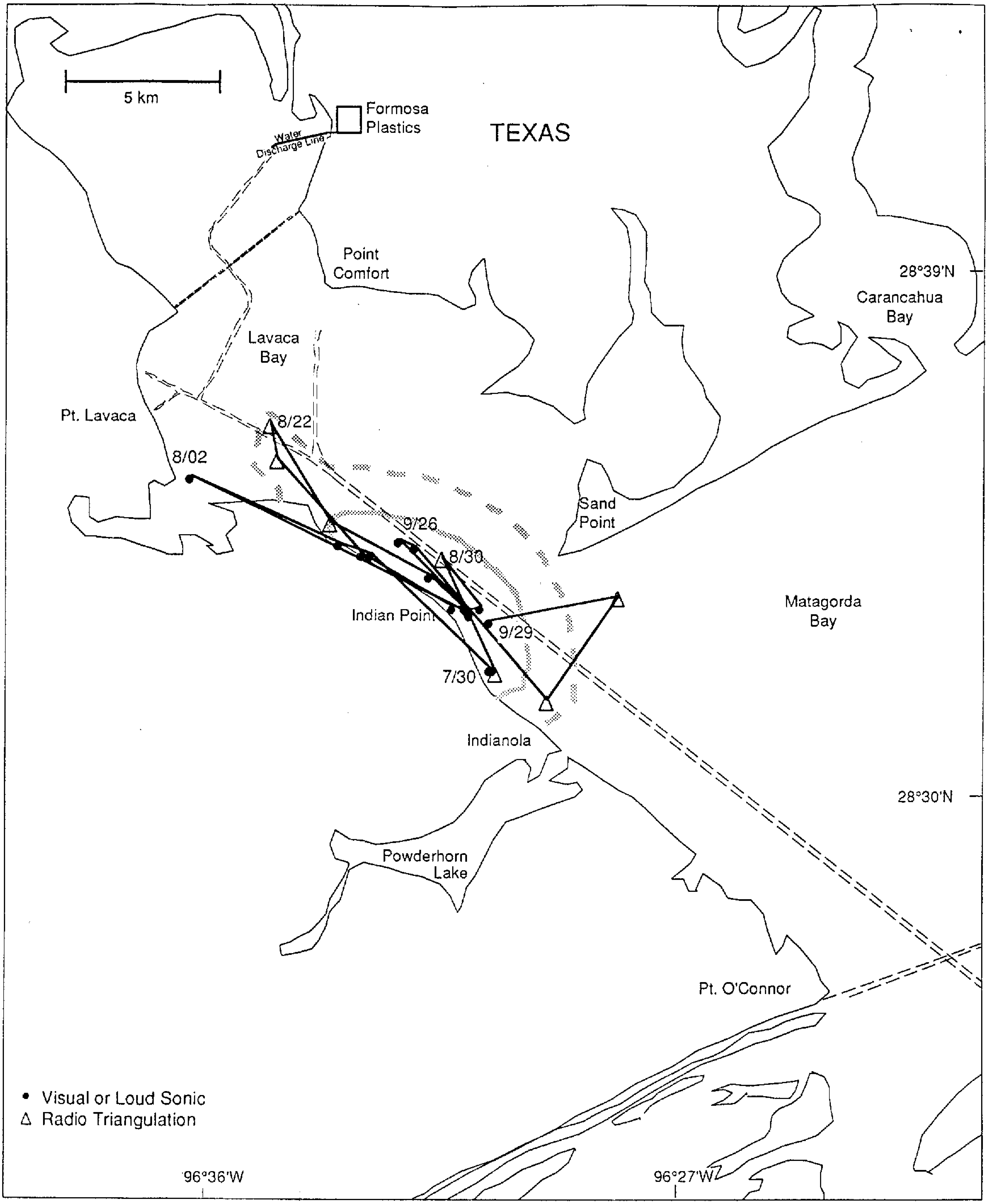

Figure 7. Movements of radio-tracked subadult female Kemp's ridley sea turtle 4391 (40.4 cm SCL) from 30 July - 29 September 1996. Home range 95% utilization distribution) is outlined with a dotted line and core area (54% utilization distribution) is outlined with a solid line.

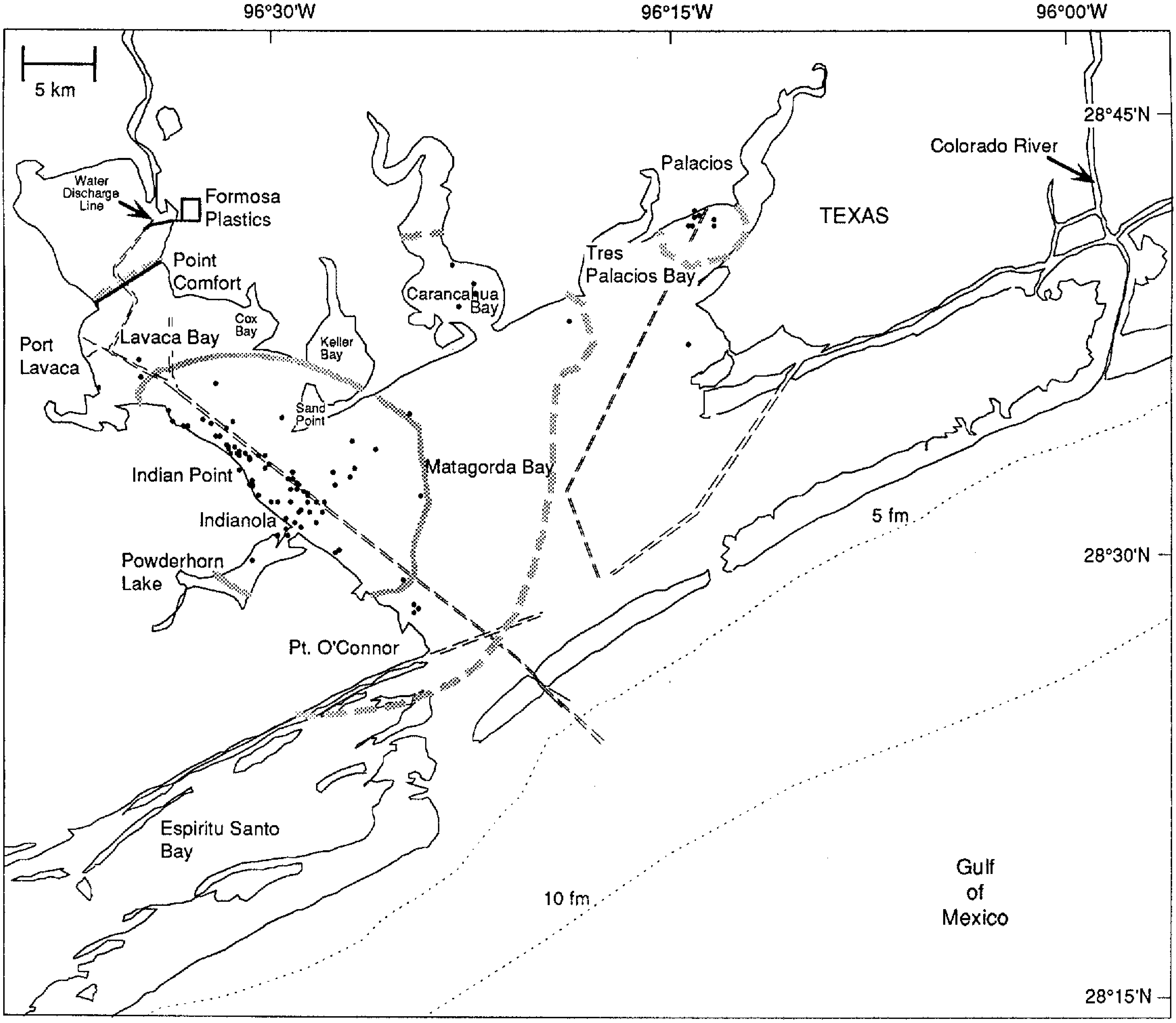

Figure 8. Home range (95% utilization distribution) and core area (64% utilization distribution) for all Kemp's ridley sea turtles combined; 28 May to 29 September 1997.

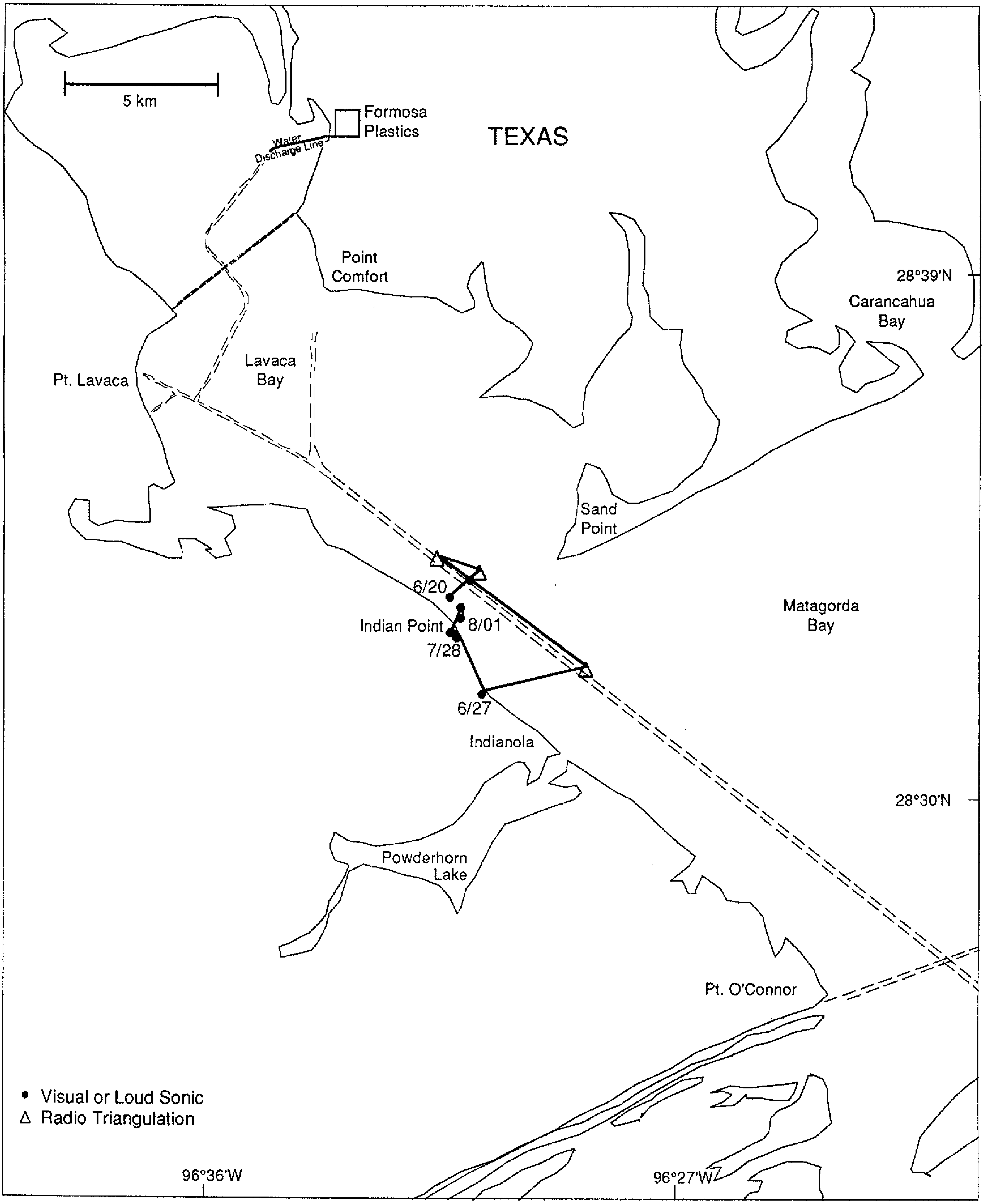

Figure 9. Movements of radio-tracked subadult male Green sea turtle 5201 (37.5 cm SCL) from 20 June - 01 August 1996.

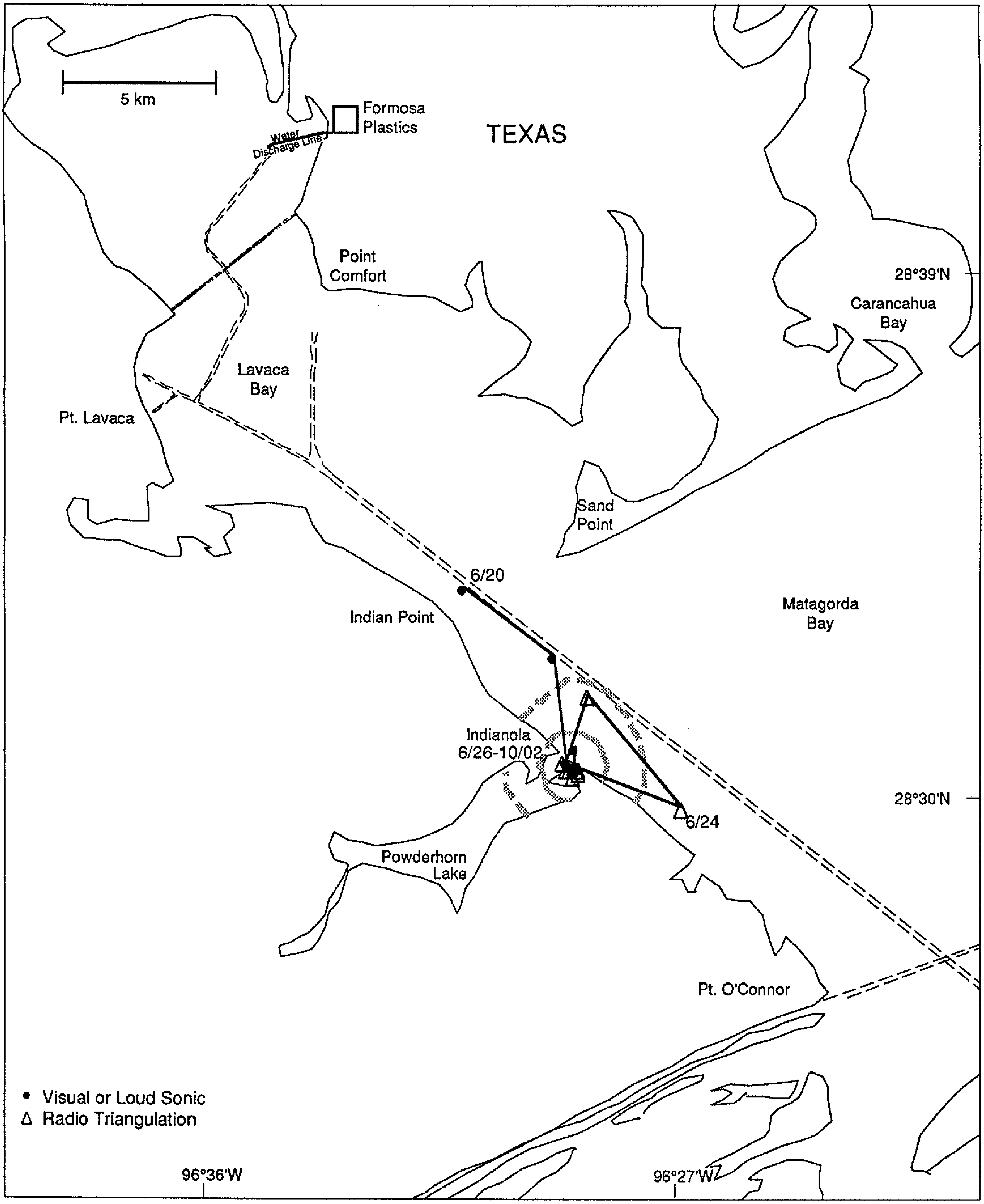

Figure 10. Movements of radio-tracked subadult female Green sea turtle 4602 (29.9 cm SCL) from 20 June - 5 November 1996. Home range (95% utilization distribution) is outlined with a dotted line and core area (64% utilization distribution) is outlined with a solid line.

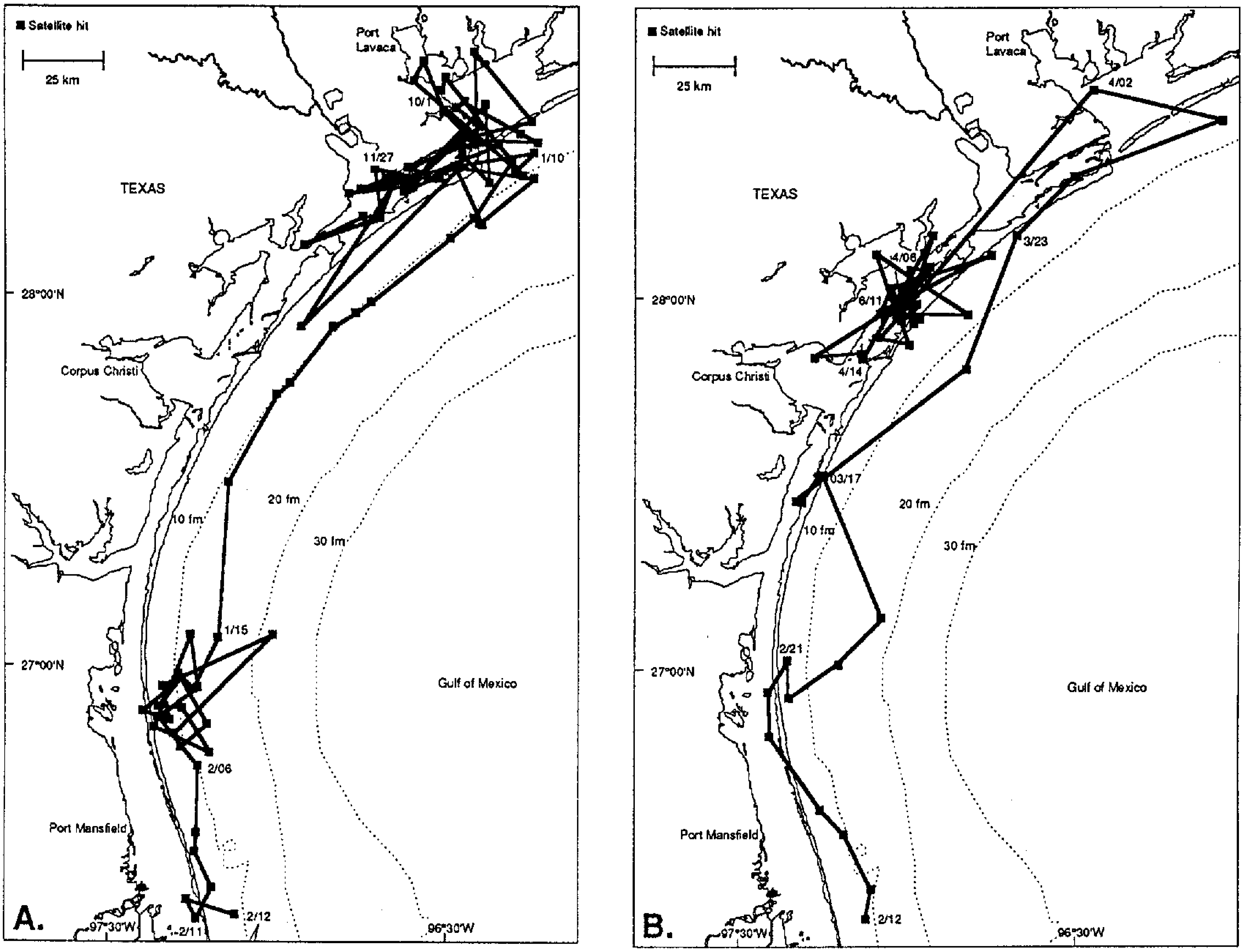

Figure 11. Movements of satellite-tracked subadult Green sea turtle 7299 (36.3 cm SCL - sex unknown) from 1 October 1996 - 11 June 1997. Southerly movement is shown on map A and northerly movement is depicted on map B.

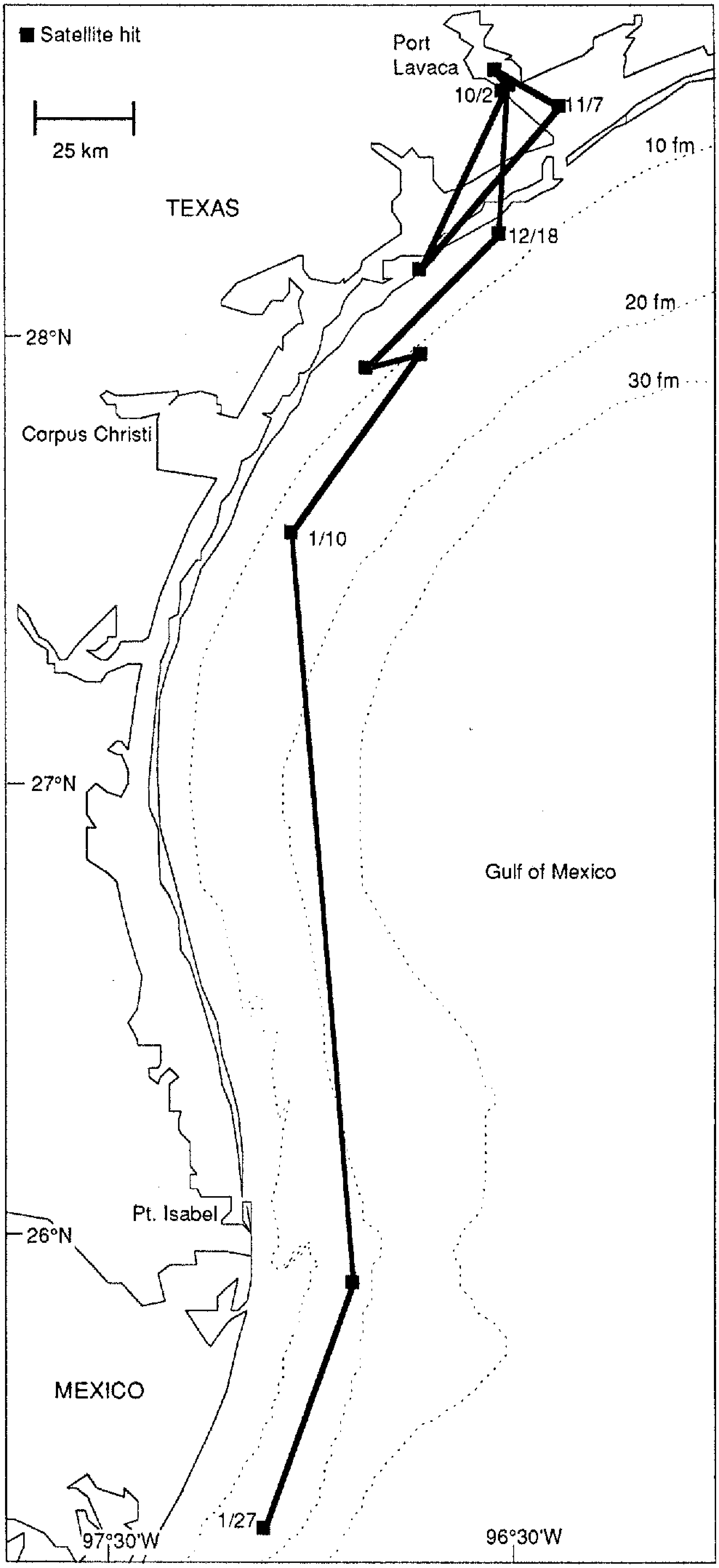

Figure 12. Movements of satellite-tracked subadult Green sea turtle 8009 (35.0 cm SCL - sex unknown) from 2 October 1996 - 28 January 1997.

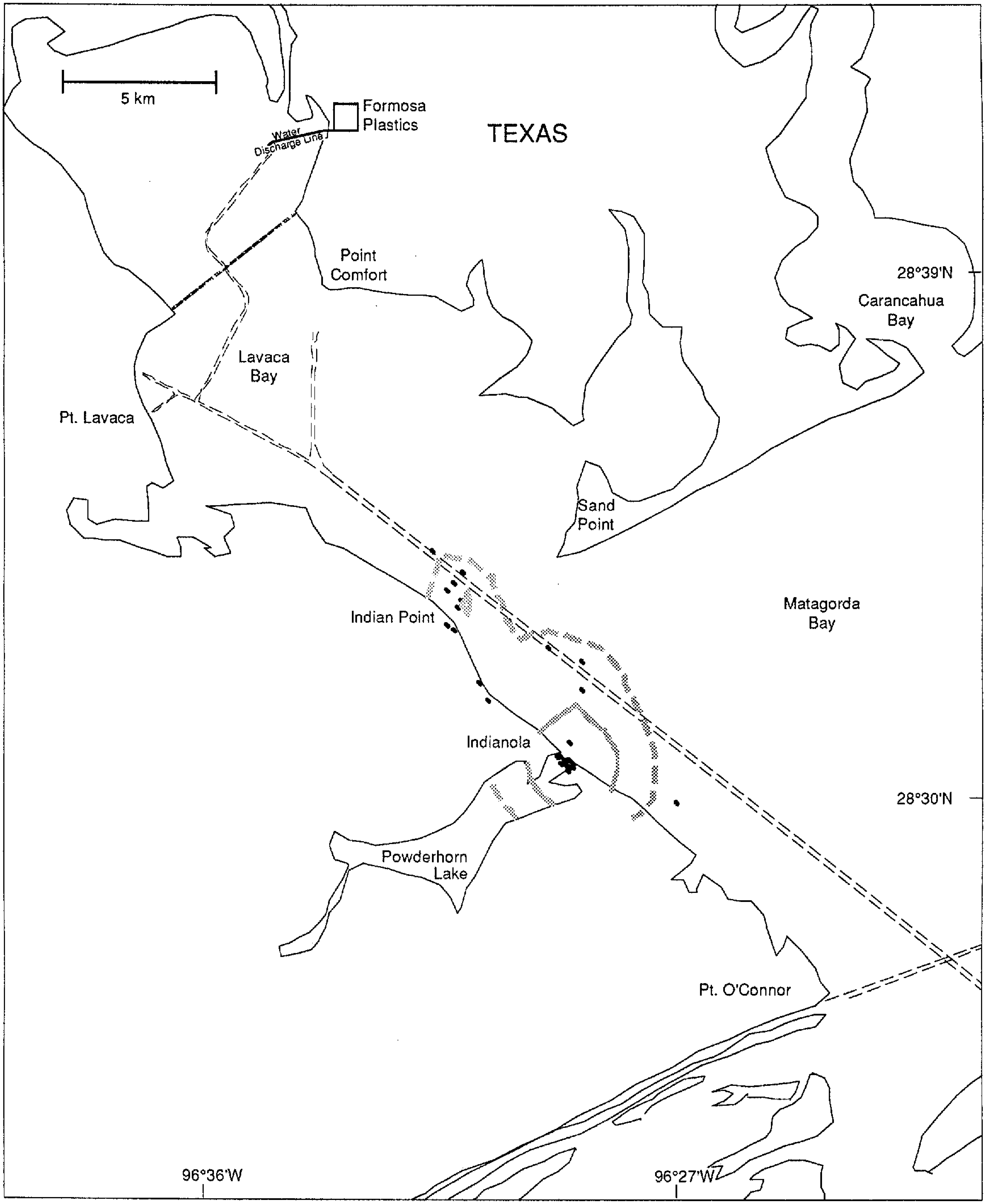

Figure 13. Home range (95% utilization distribution) and core area (53% utilization distribution) for all radio-tracked Green sea turtles combined; 20 June to 2 October 199.

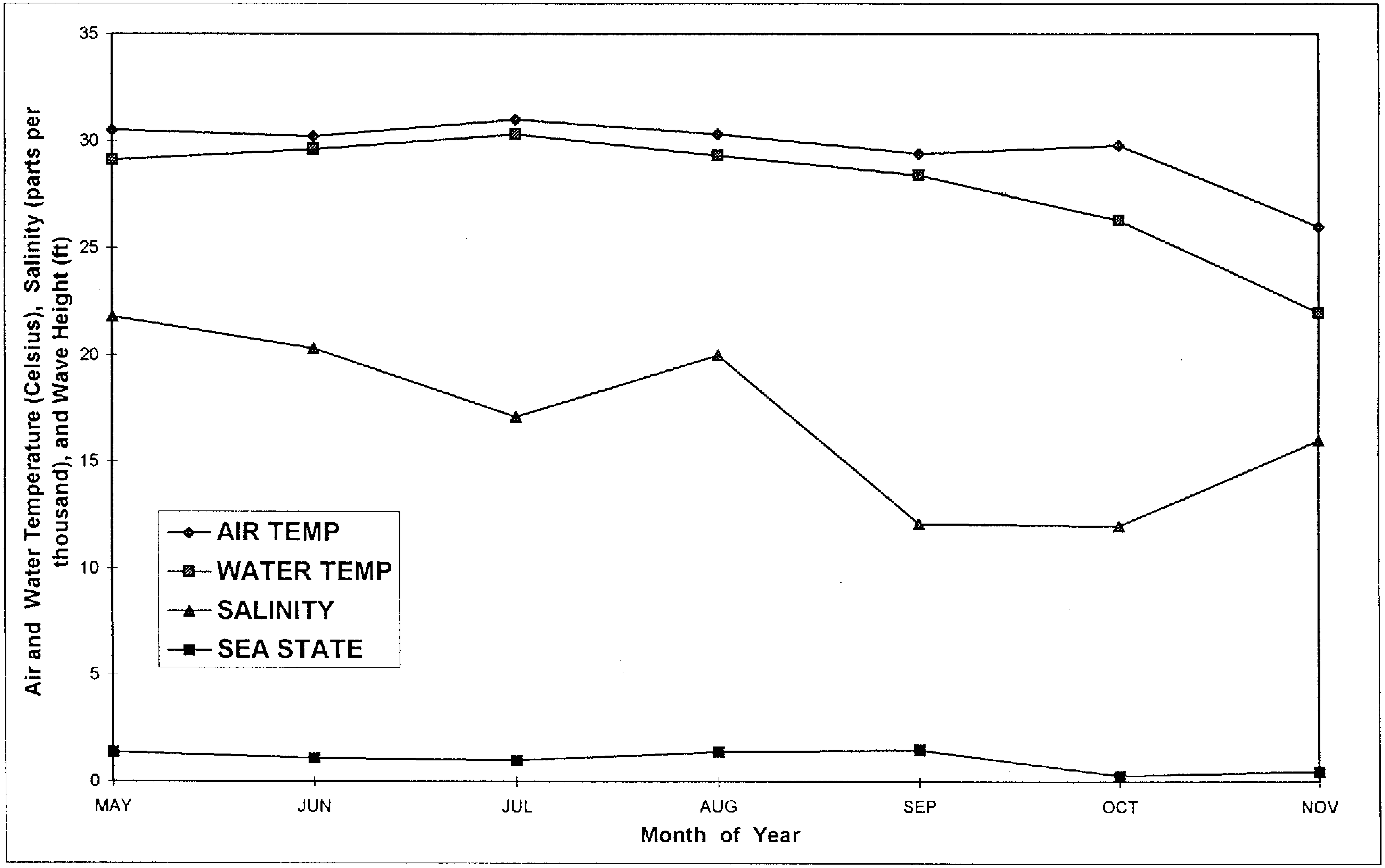

Figure 14. Monthly mean values for air and water temperature (Celsius), salinity (parts per thousand), and wave height (ft), in Matagorda and Lavaca Bays, from 28 May through 5 November 1996.

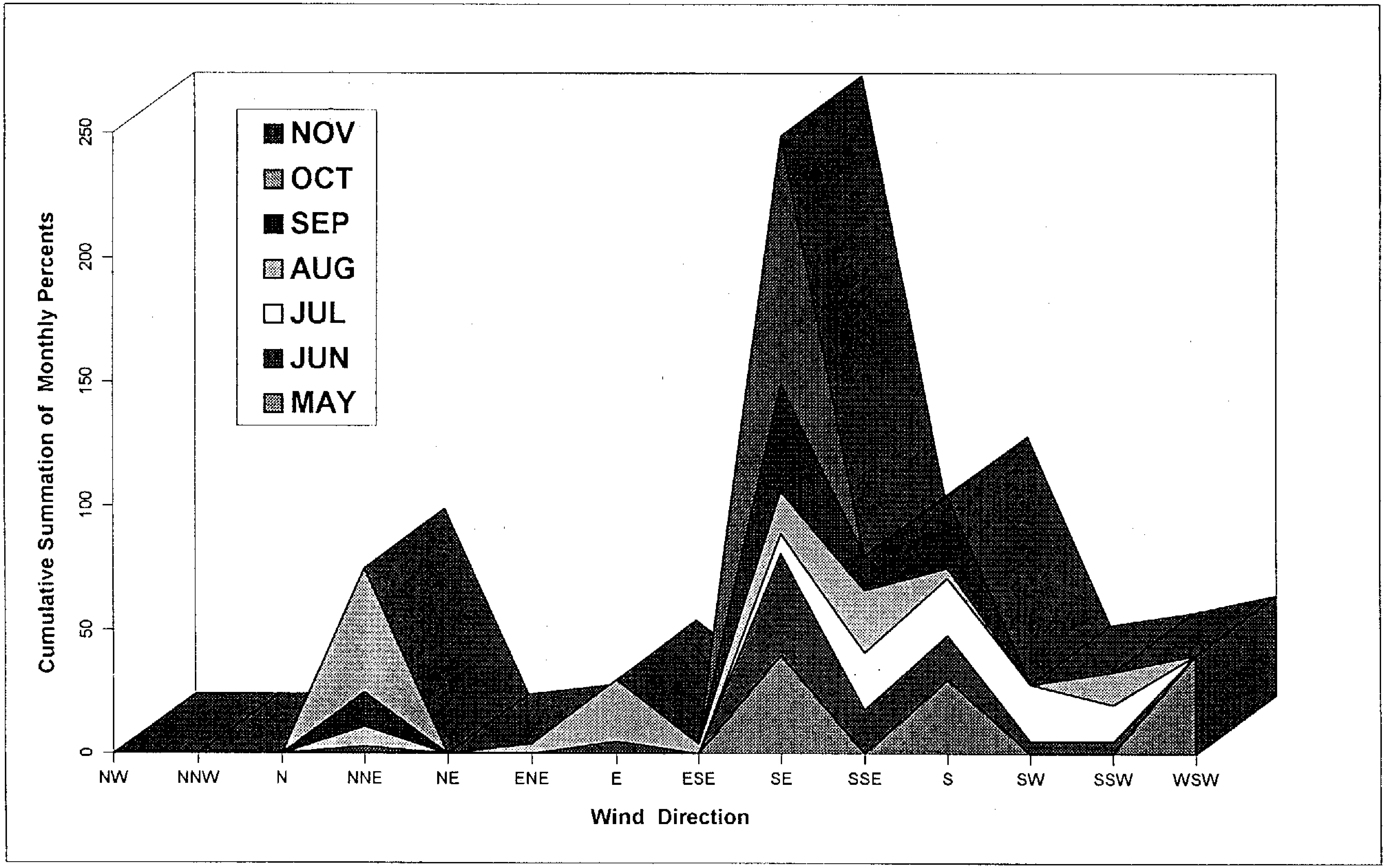

Figure 15. Wind direction in Matagorda and Lavaca Bays from 28 May through 5 November 1996, by month. The percent of time the wind was blowing in a given direction for each month is summed by wind direction.